VEGETABLE GROWING

SECOND EDITION

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VEGETABLE GROWING

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PREFACE

The large demand for *Vegetable Growing* since the publication of the first edition provided strong evidence that the book met a definite and widespread need. Much new material, the result of research and practical experience, has become available and has now been included by subjecting the entire text to a thorough revision.

The plan has again been followed of placing emphasis on research studies that have made contributions to vegetable growing practices. Soils, fertilizers, irrigation, pest and weed control, and similar subjects are discussed at those places in the text where they have direct application to the treatment of the specific vegetable crop. Chapter 15, formerly entitled "Insect and Disease Control," is now "Herbicides, Insecticides, and Fungicides"; otherwise the chapter headings remain the same as in the first edition.

The original chapter on seed production, which was said by a colleague to be "one of the subjects that everybody else has sidestepped up to now," brought forth much favorable comment. Good seed is, of course, very important, and plays a major role in the quality and yield of the crop harvested.

The classifications and discussions of varieties and hybrids now include new introductions and have been enlarged in significant ways.

New features in this edition include discussions of the following: improved cultural practices in general for both mineral soils and peat (muck) soils; the theory, using onion and carrot as examples, of why and how different seed production practices may subsequently influence the quality of the vegetable crop; the increasing importance of hybrids; pelleted (coated) seed; up-to-date weed, disease, and insect control measures; heat units for processing crops; storage (both common and cold); sprout in-

hibitors; irrigation; waxing; producing onion, tomato, and cabbage transplants; and marketing methods and containers.

An indication of the more inclusive scope of the book is the fact that information from over three hundred new references has been added in the text. Additions and changes have also been made in the illustrations.

J. S. Shoemaker

Guelph, Ontario
January, 1953

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1 · VEGETABLE SEED PRODUCTION

The vegetable seeds listed in the catalogs of most seedsmen are produced under contract by specialized growers in widely separated regions. European seedsmen, for many years, have provided much of the seed used in North America. But for a number of reasons, such as a demand for certain specific characteristics in a crop, the conditions resulting from war, and the increased information on production methods, an important, widespread, and diversified vegetable seed production enterprise has arisen on this continent.

SELF-POLLINATED CROPS

This group includes the pea, snap bean, lettuce, tomato, eggplant, and pepper. All of these are annuals, from both the ordinary crop and the seed crop standpoints.

Pea Seed Production

Most of the pea seed produced in America is raised in western regions, e.g., Montana, Idaho, Washington, California, Colorado, and Wyoming in the United States, and Alberta and British Columbia in Canada. These regions are relatively free of seed-borne diseases and certain insects.

POLLINATION. Peas do not hybridize to any great extent in the field, and seed of different varieties grown near one another can be harvested without danger of much mixing. The blossoms are seldom pollinated by insects. There should be sufficient isolation to prevent contamination by mechanical means.

SEEDING. Two different seeding methods are: (1) In rows 3 feet apart (30–40 pounds per acre), which allows for inter-row cultivation and the removal of off-type and diseased plants. This gives a somewhat better grade of seed than the second method. (2) With a drill in rows 7–8 inches apart (90–180 pounds per

acre). This method may give a higher yield but precludes inter-row cultivation and roguing.

ROGUING AND PURITY. Off-type plants are known as rogues, and the process of removing them as roguing. The rabbit-ear rogue, which often appears in some varieties, e.g., Thos. Laxton,

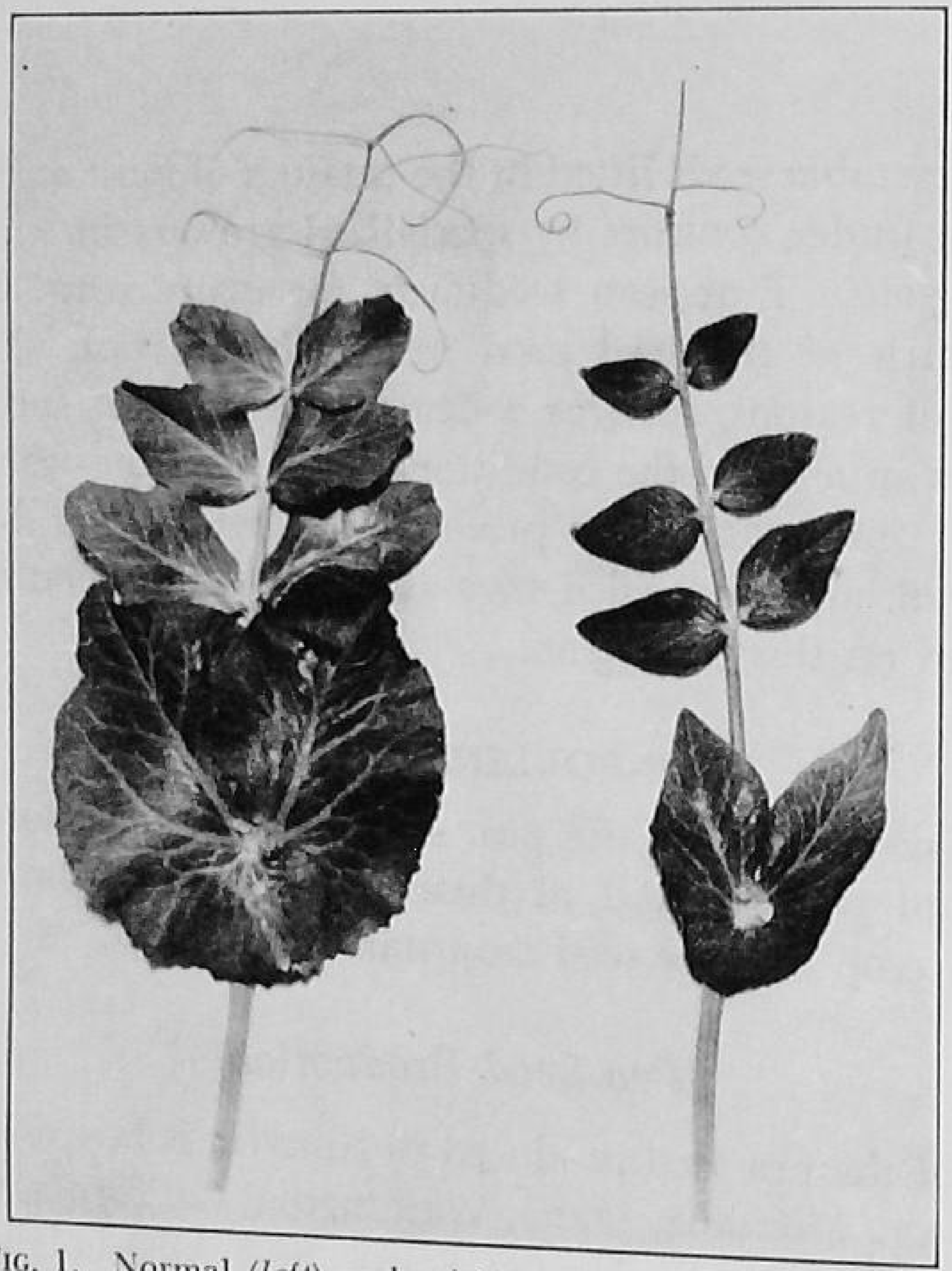

FIG. 1. Normal (*left*) and rabbit-ear rogue (*right*) in peas.

has small, narrow leaves and stipules. Early-maturing, off-type plants scattered through a field reduce the quality of the crop, especially the uniformity of the canning pack. A high standard of trueness to type allows only 1 off-type plant in 200. In order to avoid volunteer mixtures, seed should not be sown on land that has had a different strain sown on it within the preceding 2 years.

HARVESTING. The pods at the top of the plant ripen first. To avoid loss from shattering, the crop is cut when the first 25 per-cent of the pods are ripe (when the cotyledons begin to become quite tough and leathery) and the bulk is just mature. The

plants are usually cut with a mowing machine that has attachments such as guards, which lift the vines off the ground, and curlers, which move them out of the way of the mower. The cut vines are put in small bunches to cure, for at least 10 days between harvesting and threshing, to allow the "sweat" to pass. (For yield, see Table 1.)

THRESHING, CLEANING, AND STORAGE. Threshing can be done with an ordinary grain thresher, adjusted to avoid damaging the seed. The pulleys may be changed so that the cylinder runs at about half-normal speed and the rest runs at usual speed, or some of the teeth of the cylinder or concave may be removed. A combine may be used for harvesting if the plants are in rows. The threshed seed is put through fanning mills to clean out straw and light or broken seeds. Small lumps of dirt (commonly formed by earthworms), peas with hairline cracks, and stained seeds are picked out by hand. Dry seed is stored in bags of coarse open-meshed fabric in a cool, dry place.

Snap Bean Seed Production

Bean seed is produced mostly in western areas, e.g., Idaho, Colorado, and California, where seed-borne diseases such as blight and anthracnose are less of a problem than they are in more humid regions.

POLLINATION. The infolding and coiling of the lower petals hinders cross-pollination by insects. The amount of crossing is usually negligible, but about 5 percent crossing may take place in crowded fields of several varieties.

FRUIT AND SEED. The fruit is a legume (pod with a single cavity, opening along both dorsal and ventral sutures when dry). The calyx is not persistent as it is in peas, but the base of the style forms a sharp tip to the pod.

On the seed, at the point of attachment to the pod, there is a scar called the *hilum* or *eye*. Near one end of the hilum is the *micropyle;* near the other, a slight ridge, the *raphe* or *caruncle*. The seed consists largely of the cotyledons.

SEEDING FOR COMMERCIAL SEED CROP. Beans are seeded, when the danger of a late-spring frost is past, in rows 28–36 inches apart with the plants 4–6 inches apart in the row. About 1 bushel (60 pounds) of seed is sown per acre. One should not

walk through or cultivate wet bean plants, or else disease, e.g., bacterial blight and anthracnose, may be spread. In irrigated areas, the plants should not be encouraged to ripen by withholding water as this causes the pods to dry tightly around the seeds and thus increases difficulties in threshing.

Roguing and purity. Beans should be inspected often enough to remove off-type and diseased plants. Not more than 1 plant in 500 should be definitely off type, and at least 99 percent of the plants should conform to general good type for the variety.

Harvesting. Both 2- and 4-row cutters will put each pair of rows into windrows. Side-delivery rakes will combine two or more of these double rows. Small pick-up combines (4, 5, and 6 feet) are used in some areas. The vines are left in the windrows or placed in small heaps for several days to cure.

Threshing. Threshing is done much in the same manner as with peas. The seed is run through a fanning mill. Then inferior specimens such as split and spotted ones are removed by hand.

Lettuce Seed Production

Most of the world's supply of lettuce seed is grown in California, especially in the Santa Clara Valley and in the Delta section of the Sacramento and San Joaquin rivers. Some is produced in other Pacific Coast states, and in Arizona, Idaho, and Canada. A climate that is ideal for good market heads may not promote heavy seeding as the blossoms often fail to set pods in cool weather. If the climate is too hot in summer the pods do not form plump seed. This frequently occurs in the Imperial Valley with late crops, and in that very hot district the seed is made to ripen in May.

Pollination. Lettuce varieties cross only to a very slight degree. The flowers open early in the morning and remain open only ¼–½ hour. But on cool, cloudy mornings after a cool night they remain open several hours and, if insects are active then, cross-pollination may occur. It is wise, therefore, to separate varieties by 50 yards or more. Flowering continues on a single plant over a fairly long period. Seeds of any one head are ripe within 13 days after bloom.

Fruit and seed. The beaked achene is spindle or lance shaped with a number of longitudinal ribs on the surface. Most

varieties have white seeds; Imperial 847, Black-Seeded Simpson, and Grand Rapids are important varieties with black seeds.

Because of the rules defining a normal seedling, seed analysts must call reddening of the cotyledons symptoms of abnormality. Many red cotyledon seedlings, however, produce normal plants. Possibly some percentage of red cotyledon seedlings could be reported as normal, or red cotyledon could be reported as a separate part of the total germination, as is done with hard seeds in beans.[101]

Seeding and thinning. In California, the seed is drilled in rows 20 inches apart, using 1–1½ pounds per acre. The plants are thinned to 6 inches when they show the third or fourth leaf.

Encouraging seedstems. It is necessary with some harder-heading types and those with overlapping head leaves to cut or pull the head leaves apart to allow the seedstem to emerge. This is done before the head becomes hard. If it is done too soon, the plant may continue to head; if it is delayed too long, the seedstem may be injured. If the heads are not cut, many of the best type may rot. Also, if the weather becomes hot and wet the cut heads may need to be stripped (lower leaves pulled off to avoid disease). Certain varieties are often just skinned (outer leaves removed to allow the inner ones to loosen and the seedstem to come through). In nonheading types, there are no incurving leaves to obstruct the seedstem, but in wet seasons it is wise to strip off the basal leaves.

In Imperial 456, a nearly nonbolting variety, the heads form so tightly, even after slashing, that the seedstem cannot readily emerge. Hence, the tendency sometimes is to produce seed largely from those plants with the greatest propensity for bolting. Certain hormone sprays show promise[137] of producing desirable epinasty, seedstem release, and seed.

Most seedsmen do not consider the Great Lakes variety a good seed producer. High seed production in a field of Great Lakes is usually associated with undesirable market types. But even with low seed yielding but good market-type strains of Great Lakes it is possible to select for higher seed yielding types with a reasonable expectation of success. Before release to the trade, such strains need further testing for market type in the areas for which they were developed.

Roguing and purity. Plants which fail to form typical heads, do not head well, or bolt quickly are rogued out. There should be no plants with off-colored seeds. Not more than 1 plant in 300 should be definitely off type. At least 95 percent of the plants of heading types should conform to good varietal type.

Harvesting. The seed ripens rather unevenly. When the heads begin to swell and turn yellow or white the plants are cut off aboveground. Then the stalks, which are 2–3 feet long, may be laid in small piles until gathered up by hand and hauled to canvas sheets to be set upright and allowed to dry for 2–3 days.

Threshing. An ordinary thresher with some of the teeth removed serves well, although it may break up the small pod stems and make cleaning difficult. The seed is cleaned in a fanning mill. Good screen sizes are: upper, 4×8, 6×20 wire or $\frac{9}{64}$–$\frac{10}{64}$ perforated; lower, 20×20, 24×24 wire or $\frac{1}{8}$–$\frac{1}{20}$ perforated. Small lots of seed may be flailed out.

Tomato Seed Production

Tomato seed is produced extensively in several canning areas, i.e., in the Middle Atlantic States, in California, and in the corn-belt states.

Pollination. Shedding of pollen begins about 24 hours after the corolla opens. The anthers split longitudinally in a turned-inward manner so that pollen may fall directly on the stigma. The pollen tube grows slowly, even at optimum temperatures of 70–85°F. for germination and of 70°F. for tube growth.[361] Fertilization does not occur until at least 50 hours after pollination. Self-pollination is usual, owing to the type of dehiscence, the pendent position of the flowers, and because the stigmas are receptive 1–2 days before the anthers split. When cross-pollination occurs it is chiefly by means of bumblebees. Separation of varieties by 330 feet for commercial stock and by 1 mile for breeders' stock is wise.

Fruit. The fruit (a berry) consists of the pericarp, the placental tissue, and the seeds. It may weigh 9–12 ounces, in the large sorts, or only a fraction of an ounce, in the cherry type. In transection, the fruit has 2–25 locules; large canning varieties often have 25.

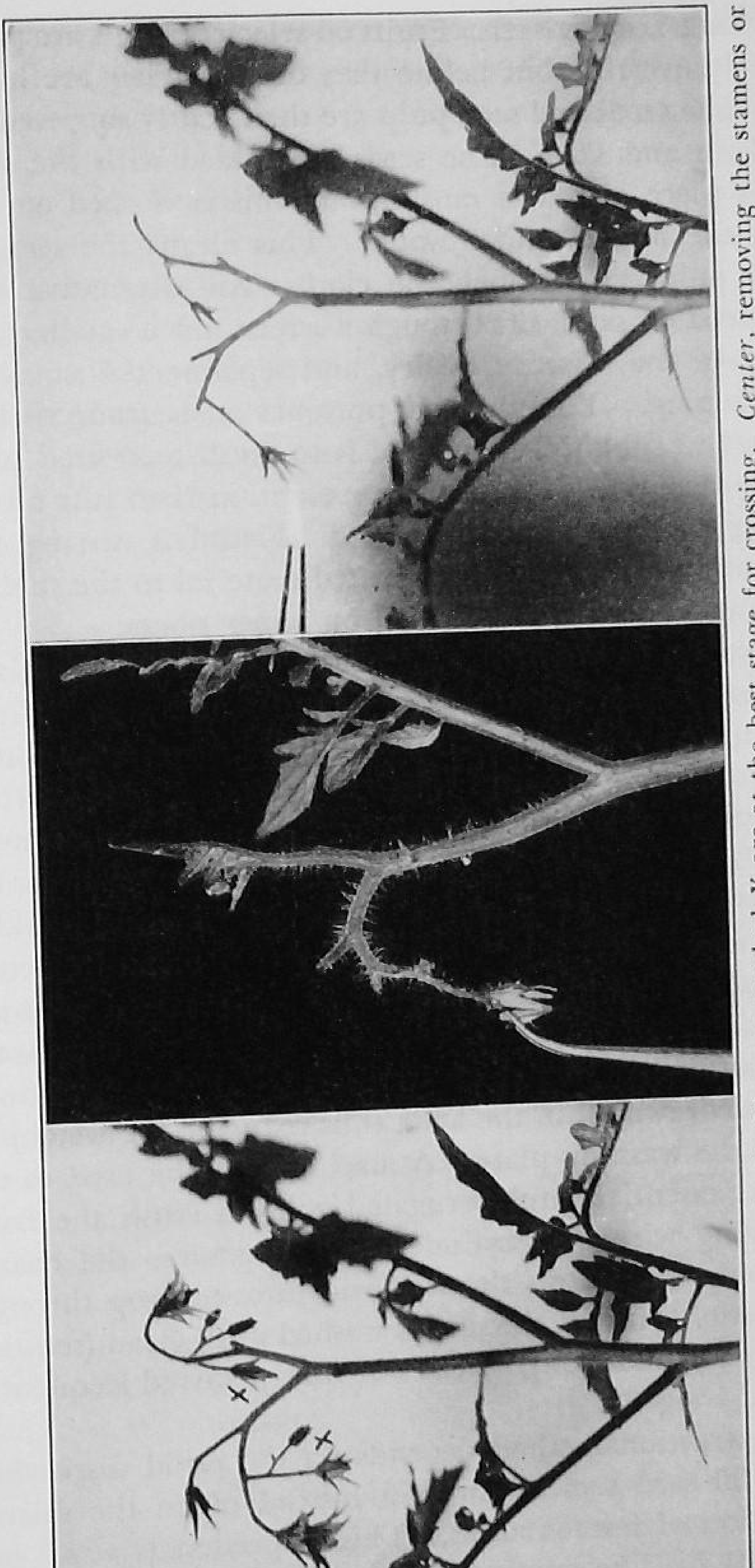

FIG. 2. Hybridizing tomatoes. *Left*, the blossoms marked X are at the best stage for crossing. *Center*, removing the stamens or male part of the blossom. *Right*, transferring pollen of another variety to the emasculated blooms. The fruit developing from such blossoms will have crossed seeds. (*Courtesy Department of Information, North Dakota Agricultural Experiment Station.*)

Saving small lots of seed. Fruits on selected plants are picked when slightly overripe but before they decay. They are halved crosswise. The seeds and seed pulp are then gently squeezed free from the flesh and skin. The seeds are folded with the softer pulp into a piece of coarse muslin, and this is worked energetically with the fingers under water. This cleans the seeds by forcing the pulp out through the cloth. An alternative is to spread wet seed on sand, sift through a screen much smaller than the seed, leave the mixture to dry, and separate the sand and seed by screening. This method prevents seeds from sticking to each other. Still another method is to crush quartered fruits into pails and cover with water. Fermentation then rots off the mucilaginous covering around the seed. Frequent stirring during fermentation brings the unfermented material to the surface. Small amounts of seed may be dried on paper plates.

Extracting commercial seed. Picking is done by hand, and the fruits are put into clean bushel hampers or boxes.

A widely used method is to crush the fruits, cover with water, and ferment for about 2 days in a vat, with frequent stirring. With longer fermentation, the seed may be damaged, but treatment for 4 days at below 70°F. helps to control bacterial canker and the seed-borne inoculum of nail-head spot. If water is added to the fermenting vats the seeds may sprout. During fermentation, much of the pulp and some seed become charged with gas and rise to the top of the vat, while the detached heavy seeds sink to the bottom, leaving clear juice in the middle. This may be tapped and drawn off in the field, thus reducing the weight to be moved to the washing place. A machine may be used to extract seed; its essentials are corrugated rolls to crush the fruit and a revolving wire-mesh cylinder which removes the coarse part of the pulp and allows the seed and juice to drop through into a receptacle. Finally, the seed is washed until clean (see also Cucumber Seed Production), spread out thinly, stirred frequently until dry, and bagged.

The acid-extraction method depends on the rapid dispersion of the colloidal seed sacs by an acid instead of on the microbiological action of fermentation. This dispersion is at its optimum at *p*H 1.2. The rate is 2 gallons of commercial HCl per ton of tomatoes. Success depends on efficient pulping and thorough mixing of the acid through the pulp by stirring.

Merits of acid extraction are: (*a*) Seed can be extracted, washed (15 minutes after the acid is added), and dried the same day the fruit is picked. (*b*) The capacity of containers for pulp is reduced to that needed to hold ½ hour's crushing instead of 1 day's crushing. (*c*) Certain fermentation difficulties of low or high temperatures, e.g., discolored seed, are avoided. (*d*) The easier and cleaner separation gives more seed per ton of fruit. (*e*) Rapid treatment of large lots of fruit by mechanical means is possible.

Purity. At least 95 percent of the plants and fruits of varieties should conform closely to type. Less than 1 percent of the vines should be definitely off type. One distinctly off-type plant may produce thousands of seeds and cause bad mixing in succeeding generations. Hybrids should conform to type approximately 100 percent.

Hybrid tomato seed. Hybrid seed production involves two selections which will combine favorably as shown by higher yields (often about 20 percent) and other merits in the first (F_1) generation.

In hand crossing, the tomato flower needs emasculation and pollination. This has been a costly part of hybrid seed production. One method of reducing this cost is to select male-sterile mother plants. With such plants emasculation is unnecessary, and pollination is the only operation needed. Once found they can be increased by cuttings. But if this is done year after year such stocks may become infected with virus diseases, and furthermore large populations of cuttings must be maintained. There are advantages, therefore, in maintaining the male-sterile mother parent variety in heterozygous condition by backcrossing; thus seed can be used to maintain the stock.

Another method of avoiding emasculation is to use semi-sterile plants with unusually long flower styles. Such blossoms when open-pollinated set poorly but when hand-pollinated set well. Since the long styles protrude beyond the staminal cone, hand-pollination is easily done.

Certain mutants [225, 324] can be selfed by hand, but they do not normally self in the field because the anthers fail to dehisce. They can be maintained as a pure line through hand-pollination and can be used as a female parent for hybrid seed without emasculation. About 75 percent of the labor involved in hybridizing is eliminated. When incorporated into other desirable

FIG. 3. Fordhook Hybrid tomato—from the first hybrid tomato seed ever offered to the public. (*Courtesy W. Atlee Burpee Co.*)

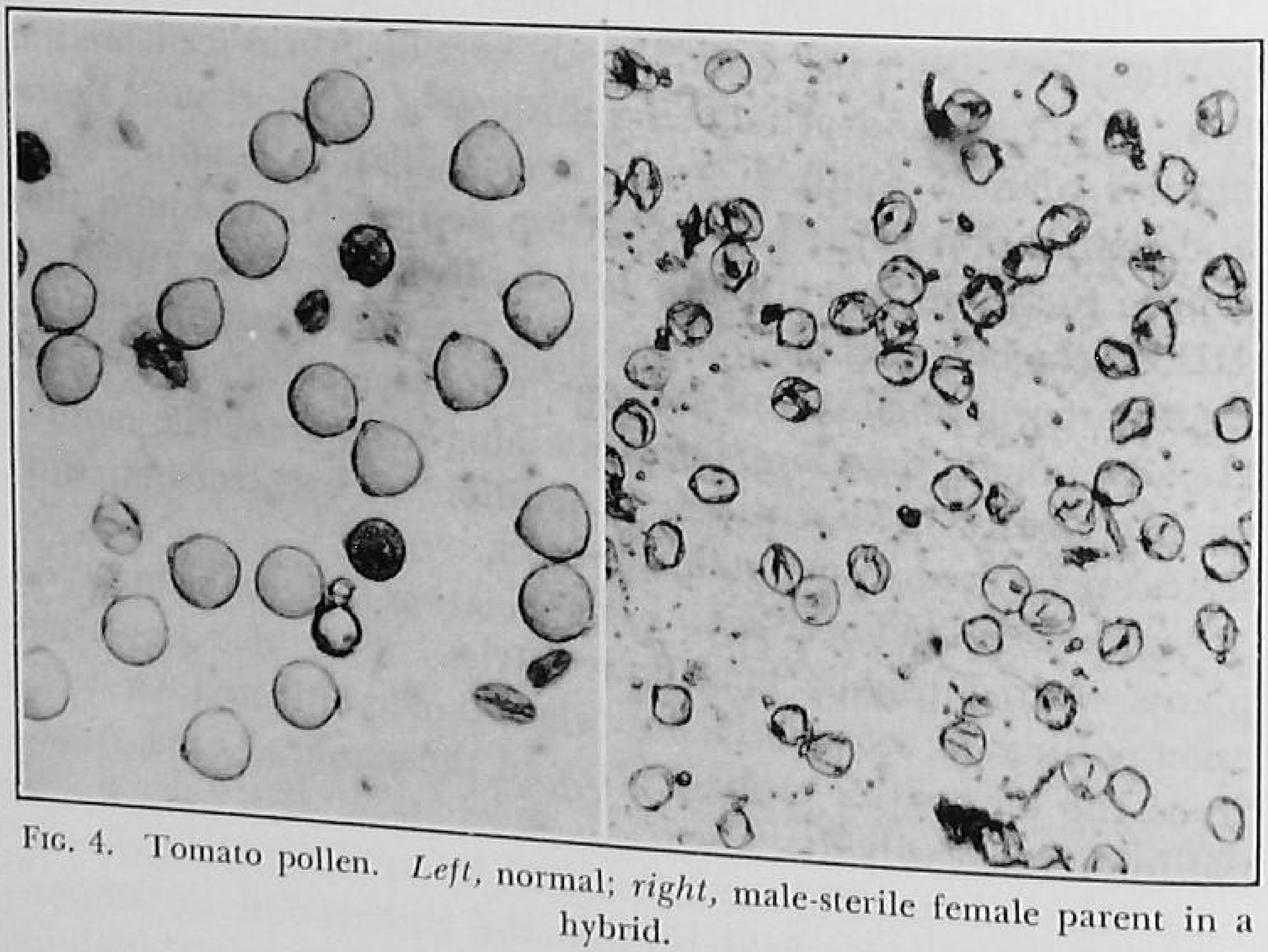

FIG. 4. Tomato pollen. *Left*, normal; *right*, male-sterile female parent in a hybrid.

parental lines, these mutants greatly reduce the cost of hybrid seed production. The best mutants for hybrid seed production are those intermediate in anther abnormality—abnormal enough for easy macroscopic identification but not sufficiently abnormal to reduce cross-pollination greatly.[319]

For F_2 generation seed, see Classification of Tomato Varieties.

Eggplant Seed Production

Eggplant flowers are hermaphroditic, and the anthers dehisce while the stigma is receptive; thus self-pollination is the rule. But insects may cause pollination as the anthers form a cone around the style with the stigma projecting beyond it. The ripe fruits are ground to a pulp, washed immediately (through two screens of different mesh), and the seed spread thinly to dry quickly. If the seed is not dry enough by night, it may sprout.

Hybrid vigor is pronounced in the eggplant. Vigorous, large, early-set plants are essential for best hybrid seed production. Generally best results are obtained from the first bud formed in each cluster. In certain varieties the fruits average 2,500 seeds. Seed from a few such fruits is enough to plant an acre.

Pepper Seed Production

Much of the commercial pepper seed production is in the Middle Atlantic states, in Georgia, and in California.

In Georgia[73] the best time to harvest pimentoes for seed is between the 50- and 60-day old (bright-to-deep-red) stages. One may harvest 30-day (mature-green) or 40-day (red-and-green-streaked) fruits before frost and ripen them at 70°F. for 30 days. The seed is dried in the sun for 1–2 days. (For purity, see Tomato Seed Production.)

Seed from either fire-roasted or oil-scalded fruits should not be used as the germination is only about 14 percent, and, of the seedlings that emerge, 5 percent show such abnormalities as adhering seedcoats, baldheads, and single cotyledons.[72]

LARGELY CROSS-POLLINATED CROPS

Distances necessary to avoid cross-pollination are not possible on many farms, and the grower may need to grow seed of only

one variety of a given type. For insect-pollinated crops, isolation of at least ¼ mile between varieties of the same species, and between closely related species, is desirable for the commercial crop; 1 mile is preferable for breeders' stock. For wind-pollinated crops, the necessary isolation, as indicated later, is even greater. In areas where vegetable seed production is concentrated, zoning is essential and may be voluntary or by compulsion. Zoning may take such forms as (*a*) growing only one variety of beet, for example, in a given district or (*b*) banning, eliminating, or eradicating kinds of plants that may cross with the ones that are being grown for seed production.

INSECT-POLLINATED ANNUALS

Lima Bean Seed Production

As much as 80 percent crossing may occur between different varieties of lima beans. This fact accounts for the placing of lima beans among the largely cross-pollinated crops.

However, in growing limas for seed in California (the chief seed producing area), bush and pole types are commonly sown in adjacent rows and often white- and colored-seeded varieties are contiguous. The percentage of recognizable hybrids in varieties of bush limas grown in California is much smaller [244] than for like varieties grown in Maryland and Alabama. When rows of Henderson, Peerless, and Early Market were surrounded by plants with contrasting characters, the recognizable hybrids in their progeny were 0.0, 0.49, and 0.71 percent, respectively. The low percentages of field crossing in California may be due to few pollinating insects or their reduced activity caused by morning fogs.

Seed production practices for limas are much the same as those previously outlined for snap beans. (See also Chapter 5.) In California, harvesting is commonly done with combines. Pole limas are grown for seed during the rainless summers near Carpenteria, Calif. The nightly fogs keep the mature pods from shattering, and so the need for hand-picking the pods is avoided.

Radish Seed Production (Spring Type)

The radish, when simply sown in early spring and not harvested, will readily produce seed. But the seed grower adopts

special procedures. Most of the radish seed crop in America is produced in Michigan and in the Santa Clara Valley in California.

FRUIT AND SEED. The mature fruit is a several-seeded pod, 1–5 inches long with an extended beak. Unlike most crucifers it is indehiscent. The oval- or egg-shaped, brownish seeds are partially embedded in spongy tissue of the placentae and septum of the ovary.

GROWING THE ROOT CROP. The seed is sown (the earlier the better) about 3 pounds per acre, in drills 3 feet apart; later the plants are thinned to 4–6 inches in the row. In a closer-spacing or broadcast method 8 pounds are sown per acre. Deep sowing results in many off-type roots.

PLANTING THE ROOTS. To maintain a choice type, the plants are pulled and the finest roots are selected. The top is cut off, leaving a few small central leaves and ¾ inch of stalks. The roots are laid in a moist, airy place for a few hours to harden; then they are set out about 6 inches apart, with the crown about an inch deep. Many seedsmen simply thin to 8–12 inches apart in the rows without lifting. Still others remove enough soil from the roots to disclose their characteristics, discard inferior ones, and leave the better roots in place.

PURITY. At least 90 percent of the roots must conform to the varietal type; 5 percent may resemble other varieties; and 5 percent may be off-type roots such as rough or pronged roots. Less than 2 percent should be off color, and less than 1 root in 400 should be purple. Some latitude may be shown in the off types as radishes may change in depth of color and form, owing to environment or depth of sowing. Plants with purple, dark-colored or yellow flowers must be removed from the seed field.

HARVESTING. When most of the pods are ripe the stalks are cut with a scythe or mowing machine and forked into piles to dry, or dried under shelter. The pods are tough, and so thorough drying before threshing is needed.

THRESHING. Two effective methods of threshing are: (*a*) with a standard separator with an attachment whereby the speed is greatly reduced and the decks, etc., travel at usual speed, and (*b*) with a combine, the cylinder speed being slowed down and adjusted against skinning or cracking. Good screen sizes are: upper $8/64$–$9/64$, lower $1/12$–$1/14$, both perforated.

Cucumber Seed Production

Cucumber seed is produced chiefly in California, Colorado, Kansas, some middle western and northeastern states, and in Canada in British Columbia, Ontario, and Quebec.

POLLINATION. Separate male and female yellow flowers occur on the same plant. The corolla of the female flower is attached to the end of a small, undeveloped cucumber. The male flowers are without any enlargement, are more numerous than the female, and appear first. Cucumber varieties cross readily, but cucumbers do not cross with watermelons, muskmelons, pumpkins, squashes, or marrows.

SPINES. In the white-spine type the fruit becomes white or a faded green when fully mature. In the black-spine type the fruit becomes yellow, orange, or brown.

SEEDING. Cucumber should not be seeded until danger of spring frosts has passed. Drilling the seed in rows is common in seed production (see Chapter 13).

PURITY. At least 90 percent of the vines should bear fruits true to type. Not more than 1 plant in 1,000 should be definitely off type. The fruit must be true in spine color.

HARVESTING. The seed is ready to harvest when the fruits have turned the characteristic mature color. Neither total yield of seed nor quality of seed is increased by regulating the number of fruits per plant.[454]

EXTRACTING SEED. In one type of thresher an iron hopper leads to corrugated large rollers or to a large cylinder and concave, somewhat like that in a grain separator. The side wall of the bottom of the hopper may act as the concave on homemade models. Either short teeth or corrugations on the roller or cylinder are effective; the objective is to crush and macerate the fruit rather than to cut it into small pieces. The crushed material goes through either into a cylindrical, revolving wire-mesh screen or onto a flat shaker screen driven from an eccentric pulley. The seed, juice, and fine pulp pass through the screen and are collected below, and the coarse pieces of flesh and skin pass off the end. The thresher may be stationary and set up at a central point, or it may be operated in the field if mounted on wheels together with a tank for collecting the threshed seed, juice, and pulp.

FERMENTATION. After the seed-bearing pulp is removed from the fruit, it is fermented for several days. The pulp is poured into barrels or tanks of water and stirred at intervals to keep the seed on top from turning black, or, with very large crops, the

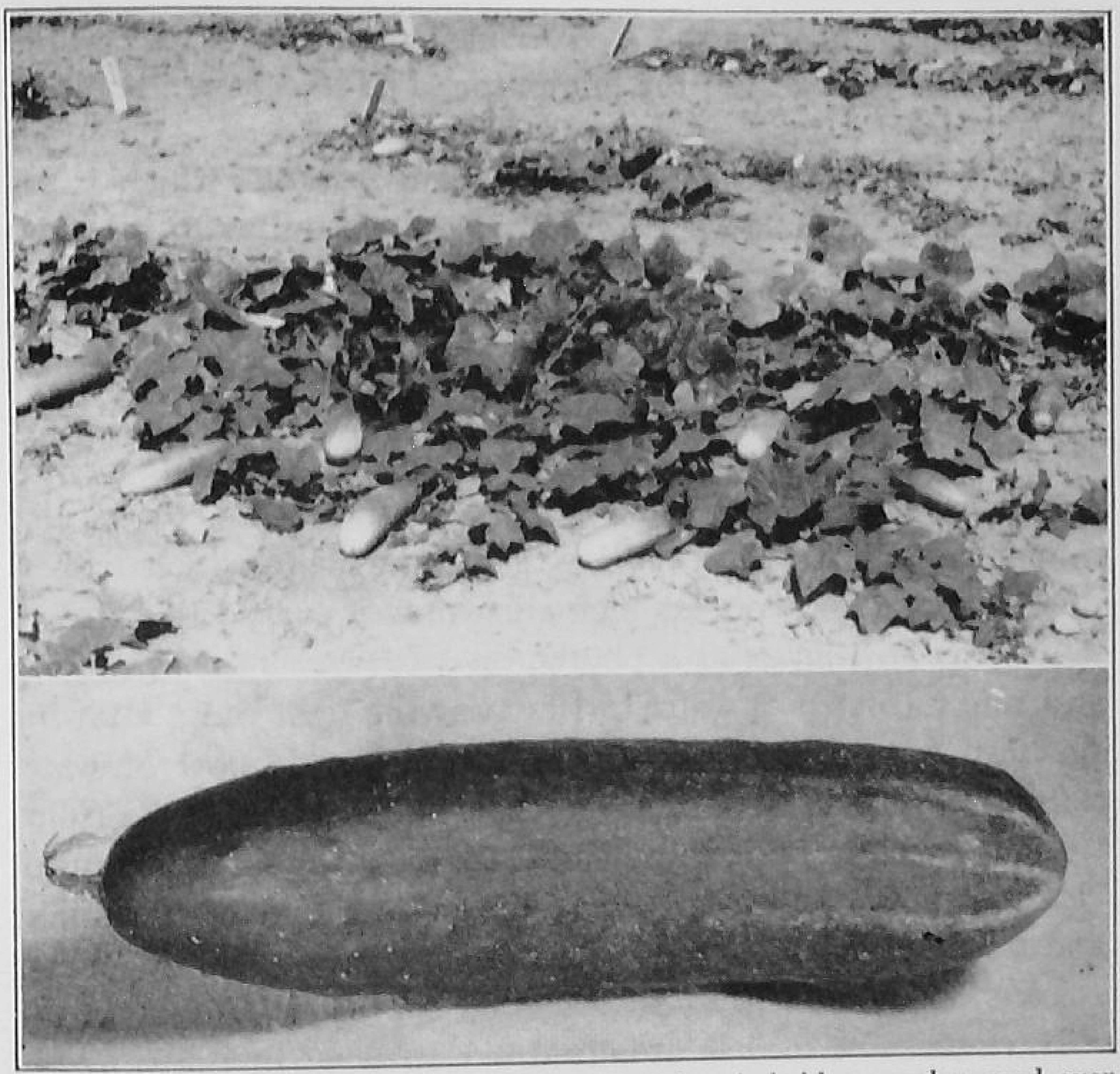

FIG. 5. Burpee Hybrid cucumber—from the first hybrid cucumber seed ever offered to the public. Note, *top*, the disease-resistant vines, and, *bottom*, the well-formed fruit. (*Courtesy W. Atlee Burpee Co.*)

fermenting material may be held in large pits lined with burlap or other material. To test for adequate fermentation, a handful of seed is squeezed; when the seeds separate freely, they are washed to remove the pulp.

With winter squashes * where no fermenting is needed as there is little gelatinous material around the seeds, the pulp can be broken down by treading, rolling, or churning with a rake. The

* Squash seed production is discussed later, but it is convenient to consider certain phases of other vine crops with the presentation on cucumbers.

seeds are light, will float in the pulp, and if churned free can be collected from the top.

WASHING. The seed-pulp mass should be washed as soon as the gelatinous material surrounding the seeds has broken down.

In the *shaker-washer,* a screen at the top removes the skins and coarse pulp, allowing the seed to pass to a finer screen which retains the seed but not the fine pulp. The screens are made up with 1 × 1 or 1 × 6 inch material for the sides. The upper screen fits into the lower, and both form a "shoe" which is suspended and power driven from an eccentric pulley to give constant agitation. The material is thrown on the top screen with a pail, and water is added to aid washing. After 10–20 pounds of seed accumulate on the lower screen, more water is added until it runs off clear. The upper screen is dumped, and the seed on the lower screen is put out to drain and dry.

The *current box* or *washing flume* consists of a three-sided flume about 10 feet long and 10–14 inches wide in which "riffles" or cross pieces 2½–3 inches high are arranged every 12–14 inches. The fermented material is poured on a coarse screen at the top end, and a current of water carries away the light pulp, allowing the seed to collect behind the riffles. A gentle flow of water suffices, as with a fast stream the seed would wash over the riffles. After the seed has piled up behind the riffles, water is run until clear. A small screen is held at the bottom end of the flume, and the riffles are lifted out. The seed is then washed down and collects on the screen.

DRYING. The seed is usually dried on trays in the sun. In British Columbia, only the earliest threshings can be dried in this manner, and so cabinet and revolving-screen driers are used.

CLEANING. The dry seed is cleaned in a fanning mill. Pieces of skin, pulp, and other refuse are removed. The wind blast should be strong enough to remove the light or thin seeds. Good sieve sizes for cleaning are (perforated metal type, in $\frac{1}{64}$ inch):

	Upper Screens	*Lower Screens*
Cucumber	16–17	8–9
Muskmelon and cantaloupe	16	9
Watermelon	24	16
Pumpkin and vegetable marrow	32–36	18–20
Squash	32–36	22–23

SEED AGE EFFECTS.[298] In laboratory tests, cucumber seed up to 18 months old germinated 96 percent at 75°F.; germination did not drop markedly until the seed was 4–5 years old. New-crop seed showed root tips within 24 hours, 3-year-old seed took 48 hours, and older seed took longer. After 6 days of germination conditions, new seed weighed about three times as much as 3- or 4-year-old seed, and ten times as much as 11-year-old seed.

In greenhouse tests, at ½-inch depth the first seedlings, from new seed, emerged in 4 days; germination was completed 5 days later. As age of seed increased, emergence was delayed and the germination period was prolonged until, with 11-year seed, the first seedlings emerged 7 days after sowing and seedlings were still emerging 9 days later. Germination was much slower at 50–60°F. than at 70–80°F.

Cucumber seed should be stored under dry, cool conditions.

Pumpkin and Squash Seed Production

The chief pumpkin and squash seed producing states are California, Nebraska, Colorado, Michigan, and New Jersey.

POLLINATION. The flowers are open, and the stigmas receptive, for a period of about 24 hours. Pollination and compatibility relationships are like those for the cucumber. Summer squash will cross with pumpkin and vegetable marrow, but it can safely be planted near winter squash.

FRUIT AND SEED. The central, hollow portion of the fruit contains a mass of glutinous fibers among which are the numerous seeds. The pericarp and undiverged tissues of the receptacle constitute the bulk of the fruit, including the rind and fibers; the connecting parenchyma disintegrates before the fruit is fully mature. The white spots on the surface are stomata or "breathing pores." (See also Fruit Color, Chapter 13.)

To obtain good germination, only *very mature* Butternut squash are suitable for seed.[450] Storage will improve the size and germination of the seed but will not make good seed from "green" squash. Butternut squash continues to set fruit until frost. Since the mature squash differs so little from the immature in appearance, care is needed in selecting the slightly darker buff color of the fully mature squash.

SEEDING. Seeding is done soon after the danger of spring frosts is over, 2–3 pounds per acre. About 5–8 seeds are sown in hills 4–8 feet apart; when the plants are about 6 inches high they are thinned to 1–3 plants per hill. The drill method is also widely used.

HYBRIDS. Yankee Hybrid, an example of an F_1 hybrid summer squash, is a cross of Early Prolific Straightneck and inbred C-10. It is noteworthy for its uniformity, attractive color, and high yield of early fruits.

Hybrid squash seed production requires precautions as to isolation, emasculation in the seed rows, and protection of purity of the hybrids. The cost of the emasculation is low enough to be practical. Pure stocks that are not more than one or two generations removed from hand-pollinated seed must be used.

Male-sterile lines have been reported in both *Cucurbita maxima* and *C. pepo.*[94]

Melon Seed Production

Melon seed (cantaloupe, honeydew, and muskmelon) is extensively produced in Colorado (where it is irrigated) and in Nebraska. The annual seed acreage in the United States is about 3,000 acres. Each fruit is cut by hand. After the seed is extracted, it is washed until clean and then dried on trays in the sun.

Melons saved for commercial seed should come from plantings grown for that purpose. It is unwise to use for seed the cull melons remaining in the field after the market or shipping season is over; the very traits that should be avoided might be the ones perpetuated. Melons for seed should not be selected at packing sheds because vine features are significant.

Male-sterile plants have been found that produce staminate and hermaphroditic flowers with small, indehiscent anthers containing empty pollen walls in tetrads.[35]

Watermelon Seed Production

Watermelon seed is chiefly produced in warm areas such as southern California and Florida, but a few firms elsewhere produce considerable quantities. The annual yield in the United States is about 750,000 pounds. Practices as outlined for other

vine crops apply also, for the most part, to this crop. The citron grows wild in some sections, is not readily recognized by the grower, and cross-pollination with the watermelon may occur. The harmful effects of the cross do not appear until the seed is grown the following year. Certain of the citron characters are dominant and result in hard, white flesh and inedible fruits.

Sprouting Broccoli Seed Production

The chief centers of broccoli seed production in the United States are California and the Salt River Valley in Arizona.

In Arizona,[147] seeding dates are August 1 to September 1 at 2,000–3,000 feet elevation, September 15 to October 15 at 1,200–2,000 feet, and October 15 to November 15 at under 1,000 feet. If seeding is done too soon, the plant will attempt to bloom before danger of serious frost is over. The seed is sown thinly in the field and later thinned; or part of the field may be sown thickly as a seedling bed and the plants thinned and transplanted. The transplanted fields usually yield less seed. The plants may be grown for seed on 40-inch irrigated beds with two rows of plants per bed, or, more commonly, in single rows on narrow beds 30–36 inches apart. Plants are thinned or transplanted 18–24 inches apart in the row.

Broccoli blooms during late February in the Salt River Valley and in March and April in the upper Gila Valley. During the seed-filling period any check due to drought will result in shriveled, nonviable seed.

Roguing. All plants that differ markedly from varietal type, that have a loose or open apical bud, and that show excess leaves in the curd should be removed. All early-blooming types should be removed from intermediate or late types or vice versa.

Removal of apical head. After roguing, all apical heads may be cut out and marketed without seriously reducing the ultimate seed yield. The apical shoot seems to inhibit the growth of the many axial or "side" shoots. Removal of the apical shoot may delay the harvest date to a slight extent, but it promotes more uniform seed ripening.

Harvesting. In areas with cold winters, sprouting broccoli is grown as an annual for seed. But in Arizona, it is one of the first vegetable seed crops to mature in the spring. Harvesting

in the Salt River Valley usually begins in early May and is completed by June 1. If the seed pod is allowed to dry in the field, much of the seed will be lost by shattering. It is usual, therefore, to cut the plants when the seeds have turned brown and have become firm and plump, but while the pod is still more or less yellowish. The plants are cut and stacked in shallow piles on canvas. When the heads are thoroughly dry they are flailed or run through a thresher.

Production of Dry Onion Sets

Onion sets ("bottom" or "Dutch" sets) are small bulbs produced from seed under crowded conditions in the field. They are miniature onions that have remained small because of the conditions under which they were grown. About 2 million bushels of sets are used annually in North America.

DISTRICTS AND SOILS. The chief production area is the Chicago district, including parts of Indiana, Illinois, and southeastern Wisconsin. Important also are the Greeley district of Colorado and the Willamette Valley of Oregon. Smaller centers are the Connecticut River Valley in Massachusetts; Toledo, Ohio; Louisville, Ky.; Canastota, N. Y.; Davenport, Iowa; and, in Canada, Montreal, Que.; southern Ontario; and southern British Columbia.

There has been a shift from mineral to muck soils for growing large bulbs. But onion sets are still produced best on mineral soils. Mucks tend to cause heavy tops and thick necks. Lake-bottom soils retain moisture well but are still friable enough not to be easily waterlogged. If a soil dries out rapidly in midsummer the sets mature before they are large enough, so that many culls and a reduced yield result. The good onion-set soils near Chicago are largely old glacial lake-bottom soils. They are very flat, and drainage is often provided for by planting in narrow, raised beds. In the irrigated Greeley district, most of the crop is produced on medium-heavy soil or sandy loam. A sandy soil requires frequent irrigation, and the walls of the beds tend to crumble.

A high plane of fertility is necessary, but too much nitrogen may promote excessive growth. Barnyard manure may be used,

but it should be well rotted so that it will not attract flies of the onion maggot or cause drying of the soil.

VARIETIES. The chief varieties are Ebenezer (yellow), Red Wethersfield (red), and White Portugal (white). The volume of yellow sets is much greater than that of white and red combined. Most sets are of varieties that have flat or oblate bulbs when allowed to grow to normal size but when crowded produce sets that are spherical or nearly so. Producing sets from hybrid seed seems promising.

SEEDING. Seeding is best done in early spring. Around Chicago the rate is 50–80 pounds per acre; at Greeley, 80–100 pounds. These rates are 20–30 times those used for large bulbs. Heavy seeding makes the plants grow in a very crowded way and reduces the normal size of the bulbs. Competition for soil moisture and nutrients stunts the plants and hastens maturity by 3 weeks or more. Even seeding and uniform stands are essential for production of sets of the desirable size of ½–¾ inch diameter. If the stand is thin or uneven, oversize sets result. These are a total loss, being of no value as sets and too small for table use.

In Ohio and Oregon a multiple-row seeder is used, 6–8 furrows about an inch apart being treated simultaneously. At Greeley, where the seed is sown on beds, two seeders are attached to a small tractor and so arranged that if one is forced out of the soil by clods the other stays in. The common 4-inch planter shoes are extended to a 6-inch width for a wider furrow. The seed falls on a plate near the bottom of the furrow and is distributed fanwise in a band 4–5 inches wide and ¾–1 inch deep. The drills are set to leave 6 inches between rows. Four-row drills are also used.

When smut is prevalent and a formaldehyde solution is applied in the furrow with the seed, the foregoing methods are not practical. In the Chicago district, where smut is common, the seed is sown thickly in a narrow furrow in rows 12–14 inches apart with 6-row gang seeders or 3-row seeders. Cultivation is done by 3-row, walking, motor-driven cultivators. Large riding cultivators taking 6 rows at a time may be used, but they are not so well adapted to the short distance between rows.

HARVESTING. In the Chicago area, sets are harvested from July to August, when the tops are yellow and dropping over. The

roots are cut with a blade that runs under the row. Pulling is done by hand. The tops are twisted off as the bulbs are placed in baskets. After some screening to remove soil, the sets are placed in crates made from 1-inch lumber with 4-foot lath spaced ⅜ inch apart on the bottom. The crates are usually 4 inches deep, 2 feet wide, and 4 feet long. Cleats nailed across the upper corners serve as handles and also provide an air space between crates when they are stacked in tiers. Each crate holds slightly more than a bushel of sets.

At Canastota, two rows are pulled at a time and left in windrows with the tops over the bulbs to cure for 2–3 weeks. At Greeley, a cutting machine with a knife that extends across the bed cuts the roots slightly below the bulbs. The sets are picked up by the tops and placed in trays that are 4 feet long and 2½ feet wide, with end walls 6 inches high at the center and tapering to the side walls, which are 3 inches high. They are provided with a center partition. A 1½–¾ inch board handle is nailed to the inside of each end to facilitate moving the crates and stacking.

Curing sets. The crates are shallow, because sets must be cured promptly. Abundant sunny weather and air movement aid in curing. The sets, stacked in tiers of 8–12 or more, each tier being covered with roofing paper, may remain in the field to cure for 4–8 weeks. Neck rot and sprouting may occur in the sets in wet weather, and so it may be necessary to take them early to the warehouse for screening and sorting.

Some onion-set warehouses have curing facilities which force through the crates air which has been dried and heated to 100–120°F. by being passed over steam coils. A drier is valuable at shipping time, because sets that become moist during storage are hard to clean.

Yields. Yields average about 400–500 bushels per acre but are sometimes as high as 800 bushels. (For storage, see Chapter 6.)

Processing. Before being distributed, sets are run through a fanning mill to remove loose scales, dust, and withered sets. They are then run over a moving belt where clods and partly rotted and sprouted sets are removed by hand. The sets then are graded. The grade diameters (maximum) may be specified as bar or screen. A 15⁄16-inch bar means that the graded sets will drop through a slatted grader in which the bars are 15⁄16 inch

apart. A $1\frac{5}{16}$-inch screen grade refers to those sets passing through a screen with a $1\frac{5}{16}$-inch square mesh. There are standards that are based on actual size of set instead of size of screen.

Processed sets are usually packed in 1-bushel, open-mesh sacks. A standard weight of 40 pounds per bushel is used at harvest, but for the processed set ready for market the standard is 32 pounds per bushel.

INSECT-POLLINATED BIENNIALS

Onion Seed Production

California (away from the coast where the drier climate favors pollination, facilitates harvesting and curing, and checks mildew), Idaho, and Utah produce large crops of onion seed. Smaller crops are grown in other northwestern states and in British Columbia (southern interior).

First-year culture for a seed crop is like that outlined later for onion bulbs. About 4–6 pounds of seed are sown per acre, somewhat more than for table onions. The extra number of bulbs per acre more than offsets any loss due to smaller size.

WINTERING THE BULBS. There are two general methods of wintering: plowing earth over the bulbs, and storage. A common practice where winters are mild is to plant the bulbs soon after they are pulled, sorted, and selected. As winter approaches, soil is plowed over the rows. In Idaho, Ebenezer and White Portugal yield best if set in the fall (before October 15). The more tender Sweet Spanish is wintered over only with some risk. Seed bulbs store well at 45–55°F., but 35–40°F. may be needed to reduce storage rots. If the bulbs are held at 40°F. or below, a shift to 45–55°F. for a few weeks late in the storage period stimulates seedstem growth.

BULB SIZE AND SEED YIELD. Large, medium, and small bulbs averaged 6.25, 3.25, and 2.7 seedheads, respectively, in Ontario.[322] The number of heads greatly affected the amount of seed produced per acre. Plants were selected, some with 6 heads, some with 5, 4, 3, and 2. The seed from each plant was kept separate. Plants with 6 heads gave the heaviest yields, $1\frac{1}{4}$ ounces per plant; those with 2 were lowest, $\frac{1}{2}$ ounce per plant. The average was $\frac{1}{4}$ ounce of seed per head.

Medium-sized (2¼–3 inches) Sweet Spanish bulbs average about 3 bulbs per pound; Ebenezer of the same diameter averages 1½ bulbs. About 7,500–10,000 pounds are needed to set an acre with medium-sized Sweet Spanish bulbs. In Idaho:[438] (*a*) a bulb 2½–3 inches in diameter if spaced properly gives a good yield; (*b*) production of bulbs over 3 inches in diameter for seed purposes probably is not profitable; (*c*) bulbs less than

FIG. 6. Onions in bloom for seed production in an irrigated district.

1½ inches are not desired, but as these permit closer spacing a uniform tonnage per acre can be maintained.

PLANTING. In California, fall planting is usual. In Idaho, planting is more customary in fall than in spring. In British Columbia, fall planting of part of the acreage, which distributes the labor over a longer period and reduces the amount of storage space needed, is favored. If the bulbs in the soil survive the winter, fall planting usually gives a larger seed crop. More loss in fall-planted bulbs is due to rot than to actual freezing. But if bulbs are planted too shallow or not hilled up, or if there is prolonged subzero weather, without snow coverage, they may freeze. Early-fall planting allows the bulbs to become well rooted before the ground freezes, but if planting is done too early more loss from rot may occur than in later plantings. In the colder areas, early spring planting is essential.

The bulbs are spaced at intervals of about their own width in rows 3 feet apart, at the rate of 2½–3½ tons of small to medium bulbs and 4–6½ tons of large bulbs per acre. Wider spacing

tends to increase the seed yield per plant but to decrease the yield per acre. The bulbs are set in furrows 3–4 inches deep and covered by hand or cultivator. Sprouts should be removed when bulbs are being planted as straighter stalks are then sent up.

QUARTERING AND WOUNDING BULBS. Large bulbs for seed may be cut in halves or quarters lengthwise. Three types of wounds were used in Utah: [430] (*a*) a longitudinal cut through the apex of the bulb, reaching about halfway through the bulb; (*b*) two cuts at right angles to each other; (*c*) the top half of the bulb cut away (Spanish method), and only the lower half planted. Wounding was beneficial, owing to earlier "come-up," better mature stand, more seedstems, and more seed from both plant and seedstem.

POLLINATION, FRUIT, AND SEED. A terminal umbel with 50–1,000 flowers is borne on a flowerstalk which may grow 3–4 feet high. The seedstems per plant are 1–20 or more, depending on the size of the mother bulb and the variety. The anthers dehisce before the stigma is receptive, and so cross-pollination by insects that visit the nectaries on the inner stamens is the rule and interpollination among flowers in the same umbel is common. Growing different varieties less than ⅛ mile apart results in much crossing. Onion and leek probably do not cross.

The fruit is a three-lobed, three-celled capsule. Each locule contains 1–2 seeds, which are black at maturity. Most of the seed is endosperm.

PURITY. At least 85 percent of the bulbs should resemble the desired type. Less than 10 percent of the bulbs should be off type (including thick-necks, doubles, and bottle-shaped bulbs) owing to soil or physical causes. Less than 1 percent of the bulbs should be off color.

It is possible to grow a field of an onion variety, such as Southport Yellow Globe, and out of it select stocks that are identical with Brigham Yellow Globe, Yellow Globe Danvers, Early Yellow Globe, or a number of others. In Southport Yellow Globe a high percentage of the bulbs are round. But in a quantity of its bulbs there will be some that are longer than normal and some that are flatter. A seed grower might feel that the ideal Southport Yellow Globe for a certain region would be flatter than normal, and he could easily select out such a strain. But if he sold both

strains as Southport Yellow Globe, his customers would soon notice the difference in shape, and so he must use a means of distinguishing between them. The new Southport Yellow Globe strain might resemble typical Yellow Globe Danvers and be sold under that name.

The same procedure could be followed with respect to earliness and a number of other characteristics. On an earliness basis, typical Early Yellow Globe can be developed from Yellow

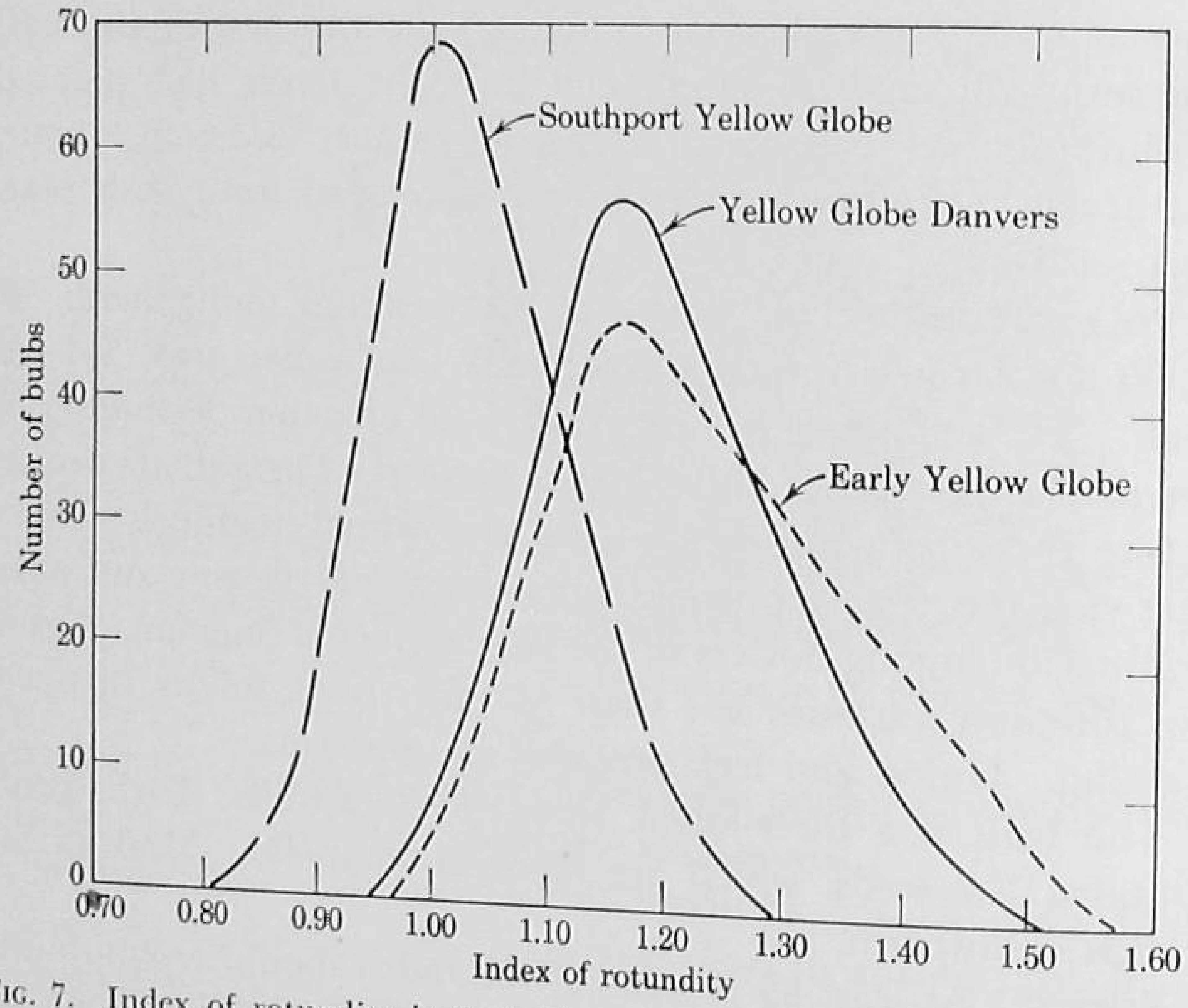

FIG. 7. Index of rotundity is the bulb width divided by the length. Bulbs with 1.0 are round, below 1.0 are longer, over 1.0 are flatter (see text).

Globe Danvers and, the latter in turn, from Southport Yellow Globe. It is not as easy to develop a longer-bulb strain of Southport Yellow Globe as it is to develop a flatter strain. In one test an attempt to develop a longer Southport Yellow Globe resulted in 22 percent of the stock being thick-necks or scallions.

Rigid inbreeding will purify a stock for characteristics such as shape but results in loss of vigor (see Purity under Carrot Seed Production).

IRRIGATION. Applying a minimum of 10 inches of water to seed bulbs at Davis, Calif., increased the seed yield.[239] It did

not materially affect the percentage of germination or the size of the seed.

HARVESTING. The seed becomes black while the grain is still watery, and so color does not indicate ripeness. The seed is mature enough for harvest when a few locules open and the heads take on a gray-green color. The seed may mature further after cutting. It is common to cut the head with a short piece of stem attached and to drop it into a sack supported around the waist of the cutter.

DRYING. The heads, with some stem attached, may be tied into bundles and hung on wires stretched over a cloth in an airy shed. Another practice is to spread the heads on shelves of wire screen in an open shed. Again, the heads may be placed on canvas sheets to dry for a day or two in the sun and then removed to a shed and spread thinly until dry. If natural drying is very slow, the heads may be dried in corn driers. If the seed is damp for over 2–3 weeks, much mold and sprouting results.

THRESHING. Undue breakage of the "button" to which the seedstem is attached should be avoided. This button, if it is broken into small pieces, is not separated easily from the seed. Wooden or rubber rollers can be run effectively over the seedheads on a canvas. A grain separator is useful if the heads are brittle dry. With combines, the heads are fed evenly onto the canvas elevator. It is better to run the material through several times with a coarse "set" than to use a close adjustment that damages the seed by excessive scarifying.

CLEANING. Seed that falls out of the heads after drying should be kept separate as it is easily cleaned. Threshed seed is rather hard to clean owing to the seedstems, pods, and especially the bases of the flowers, the last being nearly the size and weight of the seed. The top screens for the fanning-mill cleaner should be $\frac{9}{64}$ and $\frac{8}{64}$, and the lower, $\frac{1}{15}$ and $\frac{1}{14}$, perforated metal. Threshed seed is usually run through the cleaner at least twice, but the flower parts may need to be "floated off"; i.e., the seed is poured into a large vat of water, the inert material which floats to the top is skimmed off, and the clean seed settles to the bottom. The seed should not remain wet more than 3–6 hours. A drying rack consists of a suspended canvas that has a continual draft of air blown through it and the seed.

SECOND-YEAR SEED. Occasionally, a second crop of seed results from bulbs left in the ground for an extra year. But unless prospects are for at least a 60 percent stand, before work begins in the spring following the harvest of the first crop of seed, the field is best put to other use.

HYBRID SEED. Hybrid seed production is possible through the use of a male-sterile onion as the seed parent.[202] The male-sterile onion used as the seed parent is propagated vegetatively or by other means. It produces flowers which appear normal, but it does not produce pollen and so can be planted alongside another strain. Bees and other insects carry the pollen from the male to the female strain. Four rows of the bulbs of the pollenless type are planted to 1 row of the pollen-bearing select inbred. For inbreeding to develop select stock for crossing, onion plants are grown in small cages, with a few flies to scatter pollen introduced during bloom. Certain male-sterile plants tend to produce more selfs than others. By eliminating male-sterile lines in which there is a relatively large amount of selfing, the breeder can reduce the amount of selfing still further.

Hybrid onion seed was first sold commercially in 1947. By 1949, the program had expanded so rapidly that one firm had developed onion hybrids available in yellow, white, red, or brown colors, five different shapes, and classified as short-day and long-day kinds. In the onion procedure three lines are developed and maintained; hence the hybrid onion is a three-way cross.

COLD STORAGE OF SEED. Because of the high value of onion seed and its rapid deterioration under warm, humid conditions, it should be stored at 34–36°F., shipped in moisture-proof bags, and it should be previously dried at a mild temperature to below 6 percent moisture. The moisture content of the seed must be kept low whether it is cold stored or not.

Only a few days of exposure to high temperature and high humidity causes a loss of vitality of the seed. Such conditions are apt to be encountered during harvest periods with unfavorable weather or while the seed is in transit.[69]

PACKET SEED.[20] Low moisture content (3.5 percent of the dry weight of the seeds) and low temperature (41°F.) during storage increase the resistance of the seeds to harmful conditions after packeting for sale. Onion seed, upon removal from storage rooms, keeps well for 6–12 months in tin cans at 86°F. and 76

percent relative humidity, whereas in paper packets under the same conditions it may be so reduced in vigor in 3 months that good seedling stands cannot be obtained in soil, and in 6 months they may be worthless. Metal foils, e.g., vinyl-laminated aluminum foil, are good for moisture-resistant packeting of seeds.

Leek Seed Production

Leek seed is widely used in the British Isles and in European countries. About 2,000 pounds of it are sown annually in Canada.

The leek may be wintered outdoors in areas with mild winters. It is slightly hardier than the bulb onion. Plants, rather than bulbs as in the onion, are wintered, and a light furrow of soil thrown against the plants provides some protection.

The seed may be sown directly in the field in the permanent rows, or in seedling rows, later to be transplanted to the field. As only one seed head is produced per plant close spacing of 2–4 inches in rows 30–36 inches apart results in the highest yield.

Leek seed is difficult to dry, thresh, and clean. The heads are cut in late fall before the severe frosts. They are spread out in a warm place, but several months may elapse before they can be threshed. Various means are used to dry the heads, e.g., lumber kilns, corn driers, and various types of cabinet driers. A combine harvester with the rasp-bar principle makes a good thresher. Screens, about $7/64$ perforated for the upper, and $1/16$ to $1/20$ for the lower, are used when cleaning the seed.

Carrot Seed Production

Carrot seed is produced in Idaho, California, Arizona, and in the interior of British Columbia. Idaho probably produces over half of the total United States crop.[136] Curing and harvesting are more satisfactory under dry conditions than near the coast. About 2 million pounds of carrot seed are produced annually in North America.

Producing the Seed-Root Crop

Seed-to-seed method. Carrot seed may be produced in certain areas, e.g., Arizona, on a seed-to-seed basis. An objection is the lack of opportunity for root roguing and selection. Seed-

to-seed production is permissible for one generation if the seed stock is clean and if care is taken to eliminate all early bolters. These are of an undesirable root type and in one generation can ruin an otherwise good stock.

SEED-TO-ROOT-TO-SEED METHOD (CHIEF PROCEDURE). Carrot seed is rarely grown well from the large, hard roots produced from early spring sowings in northern regions, and so special sowings are made in early summer.

In Arizona,[147] where it is possible to transplant seed-roots in late January or February, seed is sown in the Salt River Valley in September, in the lower Colorado River Valley 2–3 weeks later, and in the upper Gila Valley a month earlier. The root must be fully grown by midwinter, for if the plant is immature when seedstems begin to appear in March, the seedstalks are slender and the flower heads are small.

The spacing between rows (14–30 inches) depends on the method of cultivation to be used. About 2–5 pounds of seed are sown per acre. One acre provides enough roots to set out 5–8 acres for seed the next year. In Arizona, the common 40-inch lettuce bed is used for the mother root planting. Two rows 12–16 inches apart are drilled on each bed.

In the fall, desirable roots are selected, the tops are removed without injuring the central bud, the roots are cured for a few days, and then they are stored. The largest roots need not be selected. Small ones are suitable and save storage space, but they must not be so small that the type desired is not clearly defined. Constant grading and roguing of poor specimens helps keep seed up to standard.

Proper storage for the stecklings is a serious problem in seed production. A steckling is a small seed-root, or a late-planted specimen of a root crop used for seed production.

At Parma, transplanting the stecklings in the fall rather than in the spring gave good results in 2 out of 3 years. But the odd year's results took the profit out of the other 2 years, because of a reduced stand due to winter injury.

Roots that go into a storage caked with soil, indifferently topped, or mixed with severed tops or other foreign residues are predisposed to decay. So, also, are roots that have been carelessly handled either in harvesting or storage, for even small bruises afford ideal portals of entry for rot organisms. Roots infected with rot at harvest time must be discarded prior to storage. The tops of all roots should be cleancut leaving ½–¾ inch of the petioles

attached to the root. It is wise to remove all refuse and rotten carrots from the storage and bury them in pits, to prevent dissemination of disease. Where roots are to be stored in cellars, the floors, racks, and bins should be sprayed with 1 pound of copper sulfate to 10 gallons of water. Pits should be located on clean soil and on an elevated site, if possible. If crates are not used, or if means for disinfecting crates are not available, for cellar storage it is best to pile roots not more than 2½–3 feet deep on slatted decks, leaving about 18 inches of air space between the top of the pile and the next higher deck. The storage should be kept near 33°F.[407]

Dusting with 15 percent Fermate and 15 percent Arasan may reduce storage losses.

One index of quality in carrots is the sugar content, but roots that are highest in sugar do not always store best. In favorable years the proportion of better-quality roots that survive results in high-grade seed. In bad seasons the chances of the better-quality roots producing seed are less, and, through no fault of the seedsman, he is then unable to furnish the best-quality seed.

Purity. With varieties rich in interior color, 70 percent or more of the mature roots should conform closely to the type. Over 90 percent should be of the desired rich color. Not more than 1 root in 1,000 should show evidence of wild or white carrot blood.

There is a tendency to force the term "variety" into a set mold. But in doing away with "variability," vigor may be sacrificed. Also, when the type is rigidly selected or inbred within a narrow range it can then only stand up under a narrow climatic range, and if the weather is not ideal the resulting crop may be poor.

Take as an example a stock of the Imperator. If 1,000 roots of this variety are dug and inspected they will fall fairly well into these categories: resembling Danvers, 5 percent; resembling Nantes, 5 percent; resembling Chantenay, 1 percent; resembling Oxheart, 1 percent; resembling Long Orange, 1 percent; difficult to classify, 7 percent; typical Imperator, 79 percent.

Growers would like 100 percent of the roots to be typical Imperator in shape. To obtain this the stock could be inbred and rigidly selected, all roots not ideal in shape being discarded. This inbreeding and rigid selection within a narrow range of type would "refine" the stock, but it would cause lack of vigor and limit the range of adaptability. Much trouble, known as "blowing up," occurs in highly refined stocks, with adverse results for both the seed grower and the crop producer. One

should look with suspicion on any stock of Imperator (as an example) that has more than 80 percent of its roots very distinctly Imperator in type; 80 percent typical Imperator is good stock. For both good vigor and a minimum of variability, one should resort to hybrids.

PLANTING THE ROOTS. The roots are set early in the spring with a setter, a transplanting machine, or a light spade. The soil is firmly tramped around the roots, and the crown is set even with, or only slightly under, the top of the ground. Long roots may be set at an angle of 45°. The roots should be set promptly after being taken out of storage.

In Idaho[136] when roots were removed from storage 3–7 days or more prior to planting, seed yield was reduced owing to decreased stands caused by drying out of the roots and rotting.

In Wyoming,[48] stecklings were planted on three different dates, after being out of storage for 0, 3, 6, and 9 days before each planting date. Plant survival and yield in pounds per acre of seed were higher when roots were planted at the early date immediately after removal from storage. Time out of storage before planting had no effect on seed germination. Seed harvested from roots set out at the first date of planting had the highest percentage of germination, probably owing to the greater maturity of the harvested seed.

The rows are commonly spaced 3–3½ feet apart. If roots are widely spaced to reduce the tonnage of roots needed per acre, there is a lower total yield of seed. Small roots are set closer in the row (8 inches) than large roots (12 inches). Small-top varieties, e.g., Nantes, are set closer than Chantenay. In Idaho,[136] small roots (¾–1⅛ inches diameter) give lower seed yields per acre than either medium (1⅛–1¾ inches) or large roots (1¾–2¼ inches), with little yield difference between the medium and large sizes. Because of storage and transplanting factors the use of medium-sized rather than larger roots is advised.

POLLINATION. The small, whitish flowers are pollinated by insects, the nectar being readily accessible and the compound umbels conspicuous. Failure of isolated umbels to set seed is not due, as was long supposed, to self-incompatibility but occurs because the stamens ripen and shed their pollen before the pistil is receptive. Selfing occurs only if the stigmas of the older flowers are served by pollen from the anthers of younger ones.

GROWTH HABIT. The main axis of the inflorescence terminates in a compound umbel (umbel of the first order). From the main

axis arise perhaps 13 side branches, each terminating in a compound umbel (of the second order). Each branch may also bear 2–7 side branches (of the third order). Fourth-order umbels and occasionally fifth- and sixth-order umbels are formed. Over 90 percent of the seed crop is produced on the first three orders of umbels. Since the number of umbels is established early, the position in which most of the crop is to be borne is determined

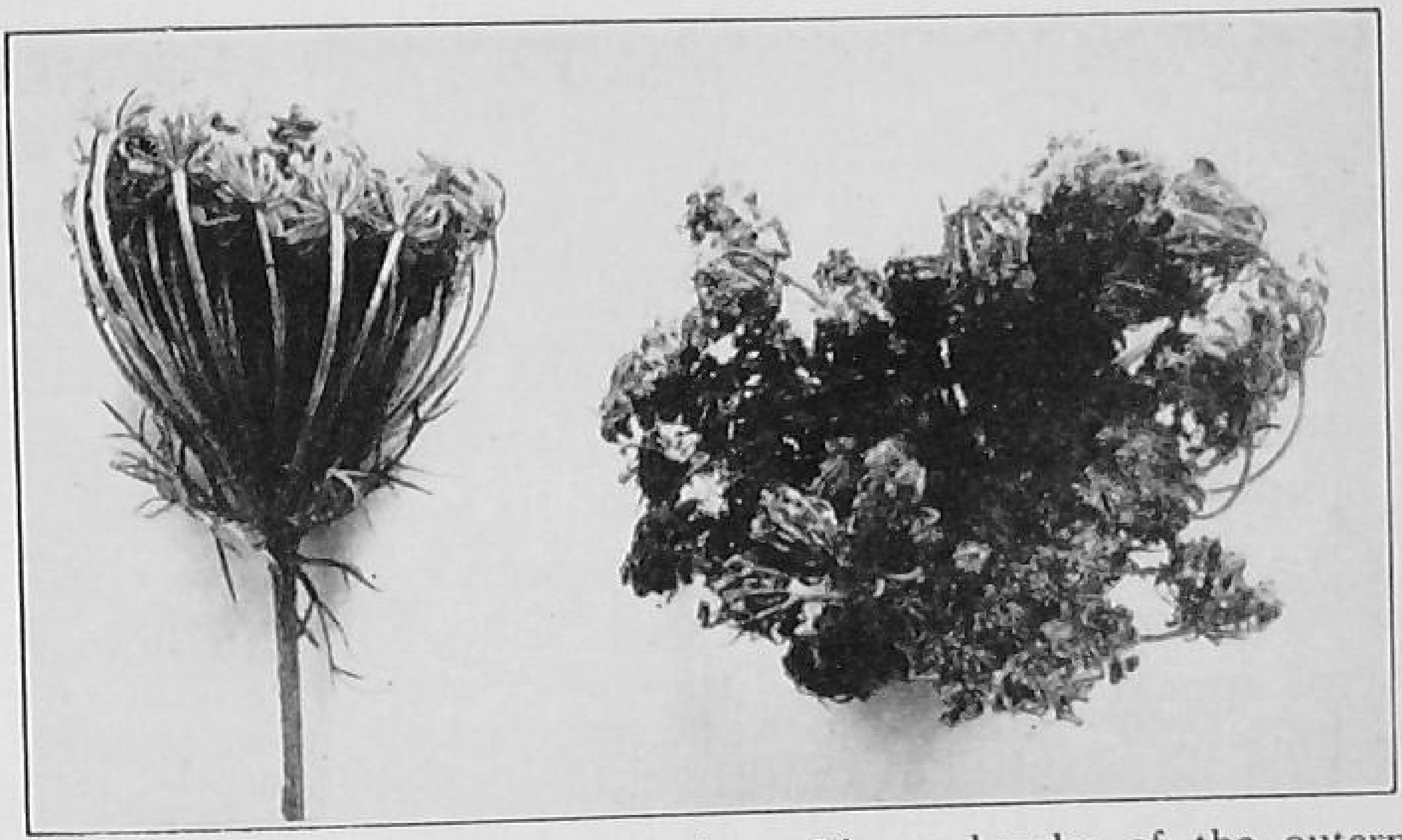

FIG. 8. Carrot seed nearing maturity. The peduncles of the outermost umbellets typically bend inwards, giving the umbel the appearance of a bird's nest. The seeds have hairy beards.

very early and is little influenced by conditions arising later in the year.

The growth habit of carrots precludes certain practices followed with some other seed crops. Beets, for example, produce their flowers in indeterminate spikes, the length and number of flowers being partly influenced by conditions during bloom; the main axis is sometimes cut back to force the lower laterals to greater development and thus keep the plants lower. In carrots such cutting would not increase the production of second-order umbels but would only stimulate the production of umbels of higher orders and so delay flowering.

Anthesis is not continuous in any one carrot plant but proceeds by waves. The second-order umbels open about 9 days after the first; the third order, 11 days after the second; and the fourth order, 13 days after the third. Pollination of the second-,

third-, and fourth-order umbels occurs about 8, 20, and 33 days, respectively, after that of the first-order umbel.

Fruit and seed. The fruit (a schizocarp) splits at maturity into two mericarps (dry carpels). Each mericarp is 1 seeded; it hangs to the forked ends of the carpophore for some time after splitting and has, on the outside, fine longitudinal primary ribs, which are modifications of the pericarp and bear long, spiny hairs. Between the primary and secondary ribs there are about 10 long spines, at the ends of which are 3–4 forked hairs.

Embryoless seeds. In 200 lots of umbelliferous seeds, the average of embryolessness in celery and parsnip was 8 percent; carrot, 16 percent; parsley, 20 percent; dill, 24 percent; and fennel, 34 percent.[132, 133, 134] Also, about 4 percent of the carrot and parsley seeds and 14 percent of the celery seeds contained immature embryos. Thus, a great loss is incurred yearly through the handling, storage, and sowing of such worthless seed. In no way can seed size, weight, or appearance aid in segregating these seeds, for both embryoless seeds and seeds with immature embryos appear normal externally.

Feeding by *Lygus* bugs (tarnished plant bugs) may be largely responsible for embryolessness in the Umbelliferae. Also, the bugs may produce injury to the growing tips of the main stem and branches and cause destruction of flower buds and umbels. Control of these bugs is, therefore, significant.

Harvesting. The seed, in its clusters, ripens very unevenly. The early-ripening heads may be picked by hand, if one can walk between the rows. Later, when most heads are mature, the plant is pulled or cut. The stalks may be bound into bundles and stooked or laid one way in a long pile like a windrow. Carrot seed, unless quite overripe, usually does not shatter readily, and so it is easier to handle than beet, turnip, or parsnip seed.

Threshing and cleaning. Small crops may be flailed. Flailed seed is more easily cleaned than that from a thresher, as the seed-stems, which are difficult to separate from the seeds, are not so badly broken up. Threshers made by using the cylinders and concaves from worn-out grain separators are effective. A combine can be fed by hand from the stooks in the field.

The spines on the seed are removed in threshing or as a separate operation later. If the thresher is homemade, the seed is first put through and then rough-cleaned. The outlet of the

cylinder is then baffled by a weighted canvas or partially closed with a metal slide. The seed is put through again, the cylinder being kept full. The seed works its way through the smaller outlet after having been churned about to remove the spines.

Combines, if properly adjusted, will scarify the seed while threshing, but it is usually necessary to put the seed through a second time, especially if damp. Many types of scarifiers and hullers will scarify cleaned seed effectively.

Large firms use a battery of two or three cleaners so that the seed travels through one machine directly to the next. The grower with one machine must put the seed through 3–5 times before the stems and inert matter are removed. Two upper screens on a cleaner are better than one. "Blanking" (covering with oilcloth or paper) about ½–⅔ of the upper end of the top screen permits less inert material, chiefly stems, to pass through the screen with the seed. Good screen sizes are: upper, 7/64, 6/64, or ½ perforated zinc; lower, 6×28 or 6×26 woven wire.

Hybrid seed. By studying the combining ability of paired inbred lines, one in each combination with the male-sterile character, it is possible to obtain very uniform carrots that are also superior to varieties in appearance, yield, quality, and health value. The feasibility of using inbred lines of corn in producing hybrid seed is due to the monoeciousness of the plant and the ease in making cross-pollinations. In perfect-flowered plants like the carrot it is impractical to employ inbred lines in this way without male sterility. There are male-sterile carrot plants, as well as plants with varying degrees of apparent male sterility,[412] that are useful in producing hybrid seed.

Parsnip Seed Production

To produce the root crop, seeding is done in early spring, in rows 3–4 feet apart, at the rate of 3–4 pounds per acre. Later, the plants, if they are to remain in the field over winter, are thinned to 8–12 inches apart.

For resetting, when selection of roots is practiced, the seed is sown in drills 1½ feet apart for hand cultivation and 2½ feet apart for horse cultivation. The plants are thinned to 6–8 inches. The spacing should be enough to give a root at least

$2\frac{1}{2}$ inches in diameter at the crown. In topping, an inch of top is left.

PLANTING THE ROOTS. Most growers produce the seed from roots left in the field over winter without careful selection. But it is desirable to dig and replant the roots early in the spring in order to discard off types. The roots may be set in a plow furrow, with a dibble or with a plant-setter such as is used for tomatoes, 8–16 inches apart in rows $3\frac{1}{2}$ feet apart.

PURITY. At least 80 percent of the mature roots should conform to type, and less than 10 percent should be off type (with fibrous side roots, or rough or pronged roots) owing to soil or climate.

HARVESTING. The parsnip is an umbelliferous plant, with greenish-yellow flowers. The seeds are produced in heads, two seeds being formed together, flat against one another. When the seed has turned brown and begun to separate the stalks are cut, laid in piles on cloths, and exposed to the sun for a few days. A dry crop is easy to thresh with a homemade thresher, a grain separator, or a combine, or it can be flailed.

The cleaning cost is high in relation to the value of the seed. Good screen sizes (perforated) are: upper $18/64$, lower 10×10 wire or $8/64$ to $9/64$. After the first run, the upper screen is blanked with oilcloth or paper leaving only 6–8 inches open at the top end to allow the stems to pass over instead of falling through with the seed. Large operators use a battery of two or three machines, blanking part of the screens of the second and third machines. The seed is then scarified for double seeds and finally put over a gravity machine.

Cabbage Seed Production

Cabbage differs from root-crop biennials in that the aboveground part of the plant is the storage place for the beginning of the second year's growth. The Netherlands, Denmark, and the Anjou district of France have been the chief centers exporting seed. In America, most of the seed is produced in the Skagit-Puget Sound District in Washington, in the Willamette Valley of Oregon, in California, and in British Columbia, where the plants can remain in the field without freeze damage. A large production area is the Skagit flats around La Conner, Wash.,

an alluvial river delta that has been reclaimed by diking and levees, and resembles certain dike areas in Holland. The Skagit Valley seed growing area has a 3-month period of very low rainfall after the seeding date, and this dry weather accounts for the scarcity of blackleg.

First-year care is outlined in Chapter 9. There are two main seed producing methods: (*a*) from loose or immature heads overwintered in the field (the cheapest method) and (*b*) from mature heads stored over winter (suitable for colder regions).

In Washington (Washington Experiment Station *Annual Report,* 1945) each variety must reach a certain minimum diameter in order to produce a maximum number of seeders the next spring. The minimum stem diameter differs for each variety, e.g., Steins Flat Dutch, $^{10}/_{16}$ to $^{12}/_{16}$ inch; Bugner, $^{12}/_{16}$ to $^{14}/_{16}$ inch; Ballhead, $^{14}/_{16}$ to $^{16}/_{16}$ inch; and Marion Market, $^{7}/_{16}$ to $^{8}/_{16}$ inch. The yields per acre were highest in those plots having the minimum-size plants needed for maximum seeding. In Skagit Island, San Juan, and Whatcom counties, there was an average of 13 percent nonseeding plants for the entire area, which represents a large loss.

Cabbage needs a rest to ensure subsequent growth of the buds into seedstems the next year. This occurs as a matter of course to plants wintered outdoors in regions where the winters are cool but not very severe. Full-grown plants in the field are unharmed at 26°F. for short duration. Where winters are severe, cabbage for seed is lifted in autumn, stored over winter, and reset the next spring.

CELLAR STORAGE. Two cellar methods are useful in cold regions: (*a*) the heads are placed upright, close together, with the roots firmly set in moist sand; (*b*) they are stored on shelves, 3–4 heads deep, with the roots of 2 rows of heads laid across each other. Slightly moist moss is then spread over the roots to prevent drying out.

STUMP PROPAGATION. Stumps from which matured heads have been cut, preferably pieces of the head with scale leaves attached, may be used to produce seed. In a cool propagating house with low humidity, the stumps may develop roots in 3 weeks and initiate the floral axis in 5–6 weeks.

TRENCH STORAGE. In Denmark, the heads and a bit of the stem are cut off and wintered in shallow trenches. In early spring

they send out roots, grow, and produce seed. In Long Island, plants are set late and do not develop marketable heads that year. They are stored in trenches, given some protection, and reset in spring. In Idaho, 3–4 heads are stood side by side in a shallow trench. The first row of heads is laid obliquely against the soil at the end of the trench, with roots downward; each successive row is laid obliquely against the one preceding. Soil is then placed 6–12 inches deep over the trench. In spring, the heads are taken out, rotten leaves are trimmed off, and the heads are set 3 feet apart in each direction.

Field overwintering. For field overwintering, young plants are set out in summer in rows about 3 feet apart. Plants of late varieties must be large at the start of winter, or seedstems may not emerge in the spring; the plants should be heading or near this stage. As cold weather approaches, soil is plowed over the heads. Just before plowing, each alternate row may be taken out. Poor heads in the remaining row are then eliminated, and the vacant spaces are filled with good heads. Another plan is to set the plants 2–3 feet apart in the rows about 4½ feet apart and to harvest from each row.

Pollination, fruit, and seed. The inflorescence is a terminal raceme. The flower has 4 sepals in two distinct whorls, 4 petals, and 6 stamens in two whorls (the outer whorl of 2 short stamens opposite each other, sometimes on a level with the stigma but generally not so high; and the inner whorl of 4 longer stamens). The yellow corolla resembles a Greek cross. The pollen surfaces of both the short and the long stamens face inward. Insects can cause either cross- or self-pollination. Cabbage family species inter-cross freely, and so one must separate them for seed.

The fruit is a long, slender silique. Seeds of the various cole crops look much alike. There is a detailed key on seeds and seedlings of *Brassica*.[261]

Planting. One method is to plow furrows 3 feet apart and 8 inches deep. The plants are set 18–24 inches apart in the furrow in a sloping position, and the soil is filled in to cover the roots and stems; the head rests on its side but above the ground; the soil is pressed firmly about the roots. Another method is to dig holes deep enough to take the whole shank and root of the plant, so that the head rests on the ground, and the soil is pressed firmly about the roots and stem. After being set by either

method, each head is cut deeply crosswise to encourage growth of the seedstem, care being taken not to injure the terminal bud.

Purity. At least 90 percent of the mature plants should conform to type. Not more than 1 plant in 500 should be definitely off type.

Harvesting. The seed ripens unevenly. Commercially, it is necessary to harvest the seed before all of it is entirely ripe; if most of the pods are ripe, those at the tips may mature after harvest. The plants are cut with a scythe or sharp spade. As the seed shatters from the pods readily, early morning, when the plants are moist with dew, is the best time to harvest. The plants are spread in a dry, airy place on canvas to ripen and cure. The canvas should be supported on brush or stakes to prevent absorption of moisture from below. The seeds heat quickly if not ripe and dry.

Threshing and cleaning. A small crop may be threshed with a flail, and a large one with a regular grain thresher. Cracking of the seed is avoided by reducing both the number of teeth in the cylinder or concaves and the speed of the cylinder. The seed is easy to clean with a mill. Good screens are: upper, 7/64 to 8/64 round-hole zinc; lower, 3/64 by 5/16 wire mesh or about 1/16 round-hole zinc. If much hulling or cracking has occurred in threshing it is wise to rerun the seed through a cleaner.

Cauliflower and Heading Broccoli Seed Production

Cauliflower seed of merit is difficult to grow, and so it is high in price. Cauliflower will produce seed well only in a moderate climate that is cool and humid at the time of setting and ripening. Most cauliflower seed has been imported from Denmark and Holland. The chief centers in the United States are in California and the Puget Sound area in Washington. A historic contribution to American vegetable seed crop production in World War II was the growing by the Ferry-Morse Seed Co. of seed of high-quality strains of Snowball in large quantity. Some seed is produced on Vancouver Island and the southern coastal area of British Columbia. Purity standards are the same as for sprouting broccoli.

Sowing seed and handling the plants. In British Columbia, seed is sown rather thinly outdoors in rows in a seedbed about

September 1–10, or in coldframes or beds in a cool greenhouse about October 1. When the seedlings reach transplanting size (in late October) they may be handled in one of these ways: (*a*) The plants are placed in 3-inch pots or bands in frames or in a greenhouse at temperatures slightly above those outdoors but not exposed to more than 2–3 degrees of frost. In February, the plants are repotted into 6-inch pots. At planting time they should be almost ready to form heads. (*b*) The plants are set 6 × 6 inches apart directly into the soil in frames or in a cool greenhouse.

CARE OF CROP DURING THE SECOND YEAR. Field planting in British Columbia is done between March 15 and April 5. Early types are set 2½ feet apart in 3½-foot rows, and later ones 3 × 4 feet. The crop needs plenty of moisture during dry spells; furrow irrigation is preferred to overhead sprinkling which aids disease. When the heads are fully formed, a wide cross section is opened in the head to loosen the curd, allow rain water to drain away, and avoid rot. A fungicide is applied soon after sections of the curd are removed, and the application is repeated if soft rot appears later.

In harvesting, the plants are cut near the ground when most of the pods have turned yellow. Cutting in early morning, when dew is present, reduces the loss from shattering. The stalks are placed on raised canvas sheets to dry.

It is an easy crop to thresh, but some of the seed may become cracked or hulled and of poor appearance unless flailed with a light rubber hose on a canvas-covered floor. The speed of the cylinder of the thresher should be reduced and, if necessary, teeth from the concaves removed. The seed is easily cleaned in a mill equipped with wind blast. Good screen sizes are: top, 6/24 round-hole zinc; lower, No. 20 woven wire or 1/18 round-hole zinc. If some seeds are cracked or hulled in threshing these cannot be removed with the ordinary machine, but the spiral-type cleaner does it effectively. Cleaned seed should be held in a cool, dry storage.

Celery Seed Production

California and the southern zone of the Intermountain Region are the chief celery seed production areas in the United States.

The plants are grown as discussed in Chapter 7. They are over-wintered in the rows or in a trench, close together and deep enough so that the tops are at about ground level. Straw and then soil are placed on top. Even if only the heart is sound by spring, they will produce a good seed crop.

Planting is done in the spring and at about the same depth as the plants stood the previous year. Seedstems soon emerge and grow 2–3 feet high. The small, greenish-white flowers are borne in flat-topped, compound umbels. A single seed (schizocarp) is produced in each locule. At least 95 percent of the plants should conform to good type. No plants should be off type in color.

As the seed will give good results even if harvested slightly green, the heads may be cut before much of the earliest-ripening seed drops. The seed is dried, beaten off, cleaned, and stored.

Turnip and Rutabaga Seed Production

In the United States, turnip and rutabaga seed is produced mostly in Idaho and the Puget Sound district. In Canada, rutabaga seed is produced chiefly in Nova Scotia. Since both these crops are cross-fertilized, the only practical means of maintaining type and uniformity of stock seed is by mass selection in reasonably mature and properly grown roots. The roots should be pulled and laid out in the row so that the type and other important characteristics can be seen.

Size of roots to grow. Mature roots are produced by the ordinary methods. Growing small roots has at least three advantages: (*a*) Since the diameter needed is only 1–2 inches, the seed is not sown till midsummer; this affords time to work the land and get rid of weeds before seeding. (*b*) Thinning is eliminated or, on well-prepared land, can be done largely with a weeder or a harrow. (*c*) Small roots need less winter-storage space than mature roots (their potential seed producing capacity being considered).

Harvesting seed-roots. The tops are cut at least 2–3 inches above the root, since the seedstem arises from the center of the leaf structure just at the top of the neck. If this portion is cut away, new buds must develop lower down, even on the shoulder, with resultant loss of energy and delay in starting. Leaving the feeding roots facilitates rapid spring development.

Wintering seed-roots. In mild climates there are two possible procedures: (*a*) The seed is sown in late summer; earth is plowed over the roots for winter protection; in spring, some harrowing or raking may be needed to enable shoots to emerge. This method requires a good moisture supply at seeding time. It is used in the Puget Sound area and in Europe. (*b*) When seed is sown in early fall in areas with a climate like that of Palouse, Idaho, winter protection is not necessary. Seed is sown rather thickly (2–3 pounds per acre) in rows 3 feet apart. The plants make a little growth before cold weather sets in and in mild periods during the winter. In spring, they are thinned to 4 inches apart. The roots remain small, but the plants soon shoot to seed and make good growth. With this method it is difficult to rogue. Dependence is placed on stock seed that will reproduce good seed with roguing for the first generation.

In cold regions, the crop is lifted and stored over winter, a laborious and costly procedure. Stored roots must be protected against both freezing and a temperature high enough to promote growth. If they are frozen after being lifted, they quickly decay; but evaporation or growth, which have the same effect, quickly sap the vigor and vitality of the root and the resulting seedstem. In spring, the roots must be held in storage until after the danger of killing frost has passed. Ordinary bin storage, where the temperature is not under control, is unsuitable. Permanent storage cellars can be used. Temporary pits can be expanded or contracted freely to suit the quantity to be stored; if the ground freezes deeply, protection is necessary.

Planting seed-roots. The roots often have sprouted when they are taken from storage in early spring, and the sprouts may break off with rough handling. Small lots are planted with a spade, two men working together. For large lots, a single furrow is opened with a plow and closed again after the roots are placed, or the whole area is turned over, and roots are placed in every third or fourth furrow, depending on the spacing desired. The top of the crown is set level with the ground or slightly higher, and the soil firmed about the roots. Large roots are spaced 24–30 inches apart each way, which allows cultivation in two directions. Small roots are placed closer, about 8–10 inches apart, in a continuous row.

HARVESTING. If allowed to become too ripe, the pods shed their seed. Harvesting must anticipate this. The seedstems are cut while the pods are still "green" but not so early as to result in poor seed. If most pods on the stalk are yellow, those at the tip will mature after curing. In some areas it is necessary to make several cuttings to avoid excessive loss. The seedstems are cut just above the crown with a sickle or with shears, bound in sheaves, and stooked till dry. Squares of canvas placed under the piles avoid loss of seed. About a week of good weather is needed for curing.

THRESHING AND CLEANING. For large crops an ordinary thresher does both the threshing and the first rough cleaning. Threshing may also be done with a combine which either picks up the dried winnowed crop or is used as a stationary thresher. The seed is put through a fanning mill to remove stems, leaves, and empty seedpods. A good, cheaply made machine for this purpose is a canvas roll that takes advantage of the mobility of the round seed. Canvas is mounted on two rollers at an angle of 30–35°. When fed on at the top end, all round, well-filled seed rolls to the bottom end into a container. The canvas is rolled by a crank device towards the higher end, and all flat portions of stem or pod are carried up and caught as they go over the top. Small seeds are then graded out. Good screen sizes are: upper, $1/12$ and $1/14$; lower, $1/20$, round-hole perforated.

INSECT-POLLINATED PERENNIALS

Asparagus Seed Production

The flowers are insect pollinated, chiefly by bees. Pollination by wind is negligible, as the pollen does not become powdery until the flower dries. The ratio of sexes is about 1 to 1 in most plantings. The fruit is a small, round berry, green when young and red when mature; it may contain 6 seeds, 2 in each of 3 cells.

Pedigreed seed involves the harvesting of seed from only high-yielding plants and continuing this program from generation to generation. There are many variations of a pedigree program. One of the most effective is to select 4 high-yielding plants, 2 male and 2 female. These are crossed, 1 male plant being used to cross only 1 female. Females resulting from one cross are

isolated with male plants from the other cross to produce commercial seed. Hence the seed traces back to 4 high-yielding grandparents.

Rhubarb Seed Production

Rhubarb varieties do not breed true from seed; hence, in the seedlings from any variety, there may be large plants and small plants, red stems and green stems, and various intermediates. The flowers are small, white, and borne on short-jointed pedicels. The flattened, rather triangular-bodied fruit contains a single seed. Victoria is a prolific seed bearer, but Macdonald produces very little seed.

WIND-POLLINATED ANNUALS

Sweet Corn Seed Production

Idaho produces about 80 percent of the North American sweet corn seed.

Pollination. Corn is monoecious. The pollen is fine, light, and well adapted to wind and gravity pollination. Insects are minor pollinating agents.

The silk is solid and somewhat flattened, with two grooves along its length. Two vascular bundles extend from its unequally branched apex through the walls of the ovary to its base, where they are continuous with other bundles supplying the spikelet. These are surrounded by slender sheath cells. The pollen tube passes down the silk between these cells until, in a few hours, it reaches the ovarian cavity. The surface of the silk is hairy, and is receptive to pollen throughout most of its length, so that the major portion of it serves as stigma.

The stigmas and styles remain receptive to pollen for 2 weeks or more after they emerge from the husks. The lower flowers start growth about a week before the upper ones, but the actual time of emergence of silk varies little more than 48 hours at the most because of the distance that the lower silks must grow. Pollen shedding begins 1–4 days after a tassel emerges and lasts 2–14 days, because the upper branches mature before the lower branches, the tips before the base, and the lower florets of each spikelet before the upper ones. Fertilization is double, 1 micro-

gamete uniting with the megagamete to form the primary endosperm nucleus. Therefore, the endosperm tissue has 3 members of each chromosome and partakes of both parental and maternal inheritance.

Xenia means that some characteristic of the male is visible in the endosperm of the seed owing to cross-pollination. This direct effect of the male gamete is conspicuous in corn because the ovary wall and the seed coat are thin and transparent. Thus, when a white corn is the female parent and a yellow corn is the male, the endosperm in the grains is the pale yellow of the male, even though the white-endosperm parent contributes two-thirds of the hereditary material.

Each grain is a true fruit (a caryopsis) like the grain of other grasses. But the whole ear is a single compound or multiple fruit.

MASS SELECTION. Mass selection means saving seed from desirable plants, bulking this seed, and sowing it *en masse*. This procedure will modify plant and ear type, maturity, and certain other points. It is not very effective in increasing yield because (*a*) yielding ability is inherited in a complex manner, and it is almost possible to find plants with only desirable characteristics; (*b*) most plants of desirable appearance have been naturally crossed with less-desirable types so that the progeny exhibit low-yielding plants as before.

EAR-TO-ROW BREEDING. Ear-to-row breeding consists in selecting ears of desirable appearance from good plants and comparing the performance of these individual ears in yield tests. Only the progeny of the best ears is used for further selections. Many modifications of this general method have been tried without success to avoid pollination by inferior plants and to prevent inbreeding. But, as with mass selection, desirable plants produce some progeny that is low in yielding ability and has undesirable characteristics. Selection is not effective in eliminating these types.

HYBRID SEED (see also Classes of Hybrids, Chapter 3)

Hybrid seed is produced by specialists who maintain the inbreds. The commercial crop of seed is produced by growing rows of the two parents in an isolated field and detasseling the female or seed parent.

Pollination technique. For inbred lines a plant with certain desirable characteristics is selected and self-pollinated. For this purpose, a transparent, heavy Glassine bag (3½ × 7½ inches) is placed over the developing ear shoot before the silk shows. The tip of the shoot is cut off to encourage the growth of a straight-topped, brush-like silk which is easy to pollinate. In a

Fig. 9. Inbreeding sweet corn. Note the tassel bags (*above*) and silk bags (*below*). (*Courtesy Chas. Walkof, Dominion Experimental Station, Morden, Man.*)

day or so, when the silk begins to show in the transparent bag, a wedge bag made of heavy kraft paper is placed over the tassel of the same plant. A day later, the tassel is cut off while still enclosed in the wedge bag. The Glassine bag is removed from the silk, and the loose pollen in the wedge bag is poured on the silk. The wedge bag, with the loose tassel still in it, is then slipped over the silk and tied securely. The seed of such a selfed plant is kept separate and sown in an individual row the next year. Frequently 100 inbred plants or inbred lines are begun this way.

In the second year, each plant in all the inbred lines is self-pollinated again. But in the fall only 1, 2, 3, or as many plants as appear desirable are selected and kept separate for seed for

the next year. The selfing and selection continue until the inbred lines are reasonably pure for the characteristics desired.

Continuous inbreeding results in plants that lack vigor, are small, and often have difficulty in reproducing themselves. But when two inbreds are crossed, the vigor of their progeny is greatly multiplied. A common effect in plants inbred for several generations is the production of weak pollen. To save them the breeder sibcrosses the inbred when he finds it is about to die out because of faulty self-pollination; i.e., he uses pollen from a brother plant in the same inbred line. Thus the inbred line is maintained without losing its hereditary composition.

Once an inbred line has been obtained the next step is to determine its ability to combine with another inbred to produce a good hybrid. The test for combining ability can be made even before the inbred has been entirely purified for its desirable characteristics, i.e., after the inbred has been self-pollinated 3 times. Normally it takes 5–7 years to purify an inbred.

It seems to us (Connecticut) a sound program to look for outstanding plants and then inbreed the ears from these, regardless of whether they were selfed or open pollinated. The success of the program of inbreeding hybrid ears points to the fact that any or all outstanding sweet corn hybrids could be profitably inbred. Such a program is now underway with inbreds from Carmelcross, Old Hickory, and Lincoln. An attempt is being made to take Carmelcross apart (by selfing), secure two new inbreds of the same maturity and recombine them into a productive hybrid similar to Carmelcross, but made by crossing inbreds that mature at the same time.

All the existing sub-lines of an inbred like P39 should be tested to see which combination produces the most productive and desirable line cross. More tests are also needed to determine whether the most productive line cross of P39 will give the best Carmelcross, Lincoln, Lee and Golden Cross Bantam when crossed by C13, C23, C27, and P51, respectively. Preliminary results indicate that the better sub-lines will produce the better line crosses, and there are theoretical grounds to believe that the best line crosses would give the superior hybrids when crossed by unrelated lines.[352]

Commercial hybrid seed. The basic production of inbred corn lines is best done by the specialized corn breeder. But the breeder may have neither the time nor space to produce many acres of corn for seed, and so he often turns over his small crops of inbreds to a grower, who, in turn, sows each in an isolated field for increase. Good isolation often means 700 feet, but if the contaminating field is the same color, type of kernel, and of somewhat similar characteristics as the seed field, then it may

be proper to reduce the distance between fields by using extra pollen rows on the sides of the seed fields exposed to the contaminating field.

Usually 2 rows of the inbred to be used as the male parent are sown together for every 3–4 rows of the inbred to be used as the female parent. This sequence is used until the field is planted. If there is a wide difference in the silking dates of the pollen plants and seed plants, then there must be a difference in the planting dates of the two in order to bring them together or make them "nick" properly at pollination and silking time.

When the tassels on the female parent plants begin to show they are pulled out by hand. This can be done either by walking through the field row by row or by riding on a machine designed to carry detasselers through a field. The field should be gone over every day while tassels are growing fast, and every 2–3 days during slower growth. The detasseling period lasts 2 weeks or so. Only the pollen from the male parent rows must be allowed to function.

Studies are being made on the production of hybrid corn seed without detasseling, and methods of accomplishing this have been explored.[201] Attempts have been made to separate selfed and crossed seed by specific gravity and color, to prevent pollen production by chemicals and heat treatment, and to maintain cytoplasmic male sterility by variation in fertility. Other methods that have been tested include: using paired progeny selection, converting sterile inbreds, producing sterile single crosses, restoring pollen fertility, and utilizing the effect of sterility on other characters.

In the irrigated Boise River Valley of southern Idaho, growing conditions are almost ideal for sweet corn, and large yields of high-quality seed are obtained. But inbreds that have been maintained there for a long time have changed perceptibly.[352] Seedsmen operating in that area should bring in fresh seed at regular intervals from the locations in which the lines originated or from areas of more adverse climate.

MATURING THE SEED. In favorable years corn will ripen on the stalk, but, because of the difficulty in drying the seed, much damage may be done by disease infection during fall rainy periods. Early fall frosts may also cause damage to late seed crops. Sweet corn spoils more quickly than field corn and is not readily cured

in large shocks, and so should be left standing to speed the drying of the ears. Where the fall season is long enough, with drying winds and little rain, harvesting may be delayed until the crop is nearly cured. The crop is then gathered, husked, and spread out to complete drying.

Contracted acreages of sweet corn seed are paid for by the seedsmen on the basis of dry weight of the seed delivered. If the crop is harvested before all dry matter is made, the grower loses because of loss of weight and the seedsman has poorly finished seed. But if seed is harvested too late, killing frosts may seriously impair germination. When the kernels reach 40 percent moisture, no further gain in dry matter can be expected.[47]

DRYING. Small lots of seed may be dried on hangers or racks. Any arrangement that holds the ears so that they do not touch one another and are out of reach of mice is suitable. Free circulation of air is essential. When dry, the seed should not contain more than 10–12 percent moisture. Artificial heat helps in drying the corn and protects it from freezing until it is dry. On a large scale, with good ventilation, quick drying is obtained in rooms where air heated to 90–100°F. is blown through special racks on which the husked ears are placed until the seed is dry enough to shell and store. The temperature should not go above 110°F., and in most drying rooms it should not be above 75°F.; too much heat devitalizes the seed.

SHELLING AND GRADING. When the corn is dry, it is shelled by machine. A good plan is first to run the seed as it comes from the sheller through a fanning mill fitted with a large screen to remove all pieces of cob and other coarse material and a small screen to remove all dirt, chaff, and very small kernels. The clean seed is then run through a grader.

For large amounts of seed, *gravity* graders save much time in the hand-picking process and save in the amount of good seed lost. *Width and thickness of kernel* graders separate round and flat kernels. *Length* graders are then used. They make the seed more uniform and attractive and permit more uniform sowing.

Pop Corn Seed Production

The procedure for the production of pop corn seed is much like that for sweet corn, including the prime role of hybrids.

To ensure maximum vigor and germination the seed ears must be quickly and thoroughly dried before sacking or shelling.

Pop corn crosses readily with other types of corn, such as sweet and dent. Crossing does not affect the popping expansion or eating quality the year that it occurs; e.g., pop corn from a field alongside one of dent corn would pop well. But this outcrossed corn should not be used for seed, because, even if the ears from the outcrossed plants are discarded in the commercial crop, their tassels will have shed pollen and thus contaminated many kernels. A pop corn strain may thus become thoroughly mixed with dent corn with a consequent lowering of its popping expansion.

Spinach Seed Production

The Netherlands, Denmark, Germany, Belgium, France, Puget Sound, Long Island, California, and British Columbia are leading centers for spinach seed. War forced seedsmen on this continent to grow their own supply. Conditions in the Puget Sound area resemble those in the Netherlands; much of the land in the Mt. Vernon section is behind dikes and below sea level, with a climate tempered in June by fogs that blow down the Inland Passage from Alaska.

INFLORESCENCE. The flowers are small. Pollen is produced abundantly over a long period, is very fine and light, and is carried chiefly by air currents. Unpollinated pistillate flowers remain receptive 2–3 weeks. There are five main sex classes:

Extreme males bear only male flowers. They are useless for gardens because of early bolting and small, thin, sharp-pointed leaves. This class is also undesirable for the seed grower, as the plants do not produce seed, and the characteristics are transmitted through the pollen to the seed bearing plants.

Vegetative males also bear only male flowers but have well-developed leaves. They bloom at about the same time as the classes listed below but do not produce seed.

Monoecious plants bear both female and male flowers on the same plant, are seed bearing, and have well-developed leaves. There is a wide range in the proportion of female and male flowers on these plants.

Hermaphroditic plants bear both female and male parts in the same flower; they may have some all-male flowers also. They are seed bearing and have well-developed leaves.

Female plants bear only female flowers, have well-developed leaves, and produce seed.

FRUIT AND SEED. The fruit is 1 seeded (a utricle). There are two types of seed, prickly and round. Both are closely enveloped by the persistent hard cartilaginous calyx or by calyx-like bracts. In prickly-seeded varieties the bracts are drawn out into 2, 3, or

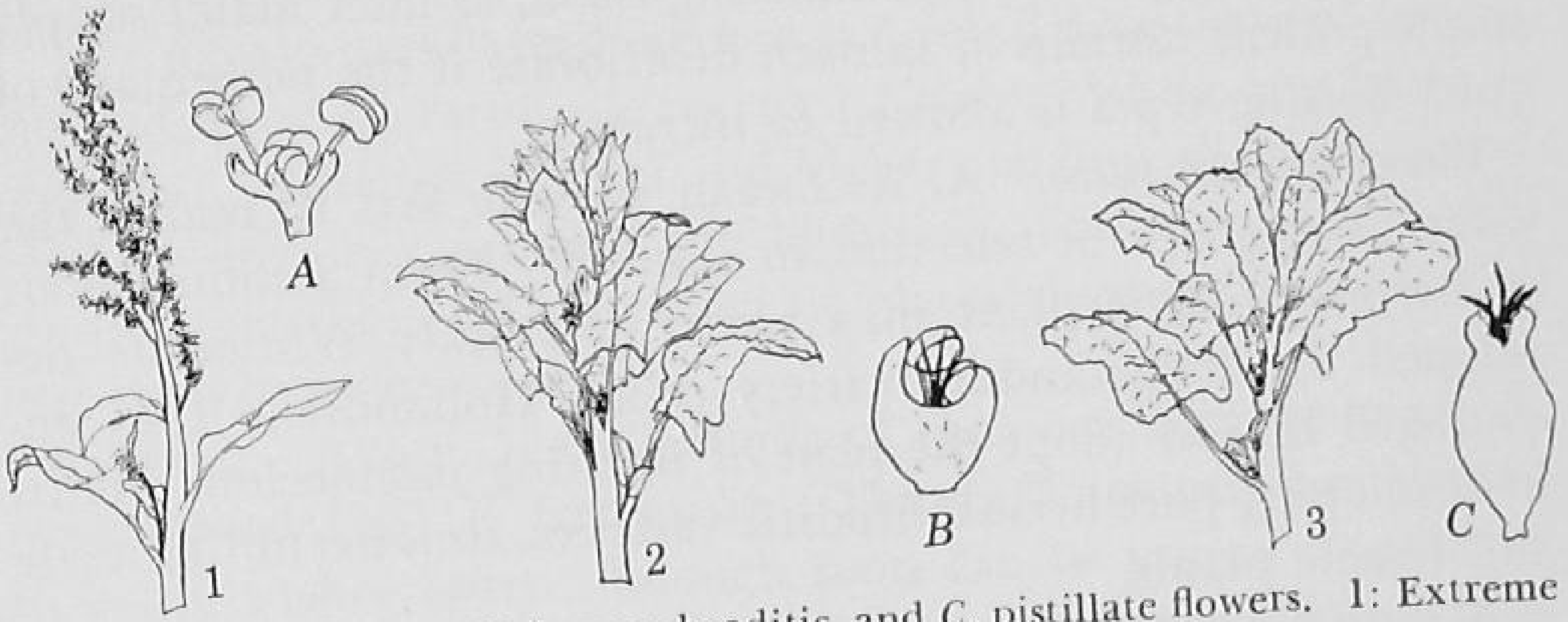

FIG. 10. *A*, Staminate, *B*, hermaphroditic, and *C*, pistillate flowers. 1: Extreme male plant bearing staminate flowers. 2: Vegetative male bearing staminate flowers. 3: Female plant bearing pistillate flowers. Monoecious and hermaphroditic plants may resemble 2 or 3 or any intermediate of these two, the monoecious having staminate and pistillate flowers, and hermaphroditic plants having flowers as in *B*. Still another type of plant, which resembles 2 or 3, may have staminate and hermaphroditic flowers, or there may be pistillate and hermaphroditic combinations.

4 horny projections or spines; these are lacking on the round-seeded varieties.

SEEDING. The seed may be sown in fall or spring, though the fall-sown crop, in favorable areas, produces the highest yield of seed. The seed, 10–12 pounds per acre, is sown in rows 2–2½ feet apart, and the plants are thinned later to 4–6 inches.

SOIL. Spinach seed is best produced near large bodies of water where the temperatures are uniformly cool, where rainfall is adequate in the growing season, and where the relative humidity is high. Spinach seems to need the conditions that occur in soils near salt water, certain "plant foods" that come from decomposed sea life, and certain minerals that appear in land once covered by salt water.

PURITY. Spinach varieties must be separated by ½ mile for commercial and 1 mile for breeders' stock seed. At least 99

percent of the plants must conform to type. The extreme male plants must not exceed 2 percent.

Effective roguing depends, in part, on an adequate spacing of the plants obtained by seeding thinly or by thinning. At the first roguing, before flowerstalks appear, plants not true to varietal type are removed. At the next roguing, early bloomers are removed; most of these are extreme males, and hence yield of seed is not reduced by eliminating them, as later males supply ample pollen. Strains of spinach deteriorate if the percentage of quick-bolting types is allowed to increase.

Breeding methods. A. R. Zwaan was the first to realize the value of single-plant selection in spinach. From a monoecious or hermaphroditic plant in a strain of Prickly Winter he developed the long-standing variety called Hollandia. This encouraged him to adopt the plan of isolating monoecious plants in developing pure hermaphroditic varieties, thus excluding male and female plants.

A pure hermaphroditic line can be raised for one generation, but eventually it will produce some male and female plants. Princess Juliana was bred from a monoecious plant and showed the possibility of producing strains without extreme males. The single-plant selection method has resulted in Longstanding Bloomsdale, Nobel, and others.

Harvesting. The seed matures slowly and unevenly. When the plants begin to turn yellow, they are cut with a scythe or mowing machine and placed in piles to dry. Since the seed from dry plants shatters badly, the plants should be cut before they are fully mature.

Threshing. One plan is to place the seed clusters on canvas sheets and separate the seed by means of rollers. With machine threshers, hand rubbing or rolling is not necessary. The seed is easily cleaned, if the clusters have been well broken up, by any cleaner having proper screens and wind blast strong enough to take out most light and immature seed. The top screen is about size 12/64 round-hole zinc. The bottom screens, which must allow the greater percentage of undersized seed to pass through, are 1/12 by 1/12 wire mesh or 6/64 round-hole zinc.

WIND-POLLINATED BIENNIALS

Beet Seed Production

France has been a large exporter of beet seed. In the United States beet seed is produced in a number of western areas that happen to be free from curly top. In Canada, beet seed is produced in British Columbia, Alberta, Ontario, and Quebec.

The seed-to-root-to-seed method is favored over the seed-to-seed method, even in certain areas, e.g., Arizona, where the latter is possible. Although cheaper and higher yielding, the seed-to-seed method does not produce the highest-quality seed as the only grading possible is the removal of plants showing variations in leaf type or color.

SEEDING. About 15–20 pounds of seed per acre are sown in rows spaced 1½–2½ feet apart. The seedlings may be thinned to 2–2½ inches apart. Enough roots can be grown on an acre for 5–20 acres of seed-roots the next year. Another plan, which saves labor in weeding, is to sow 6–10 pounds per acre in single rows 14–16 inches apart and to thin the seedlings to 4–5 inches.

SIZE OF SEED-ROOT. Usually the best seed-roots are grown from seed sown in early summer, but it may be difficult to get a good stand then if there is a dry spell. Hence a low or moist piece of ground, or ground where water can be applied, may be best. Large roots (6–20 ounces) probably produce more seed on poor or average soils; but on rich soils, small seed-roots (2–6 ounces), ¾–2 inches diameter, often outyield larger ones. With the larger diameters, increased yield may be due to more basal branches. But because more small roots can be grown in a given area with less labor in digging, storing, and planting, they are favored commercially.

In Arizona,[147] in order to obtain roots 1–2 inches in size, sowings for seed-to-root-to-seed production are made September 1–30 at elevations of 1,000–2,000 feet, and August 1–25 at elevations of 2,500–3,500 feet.

HARVESTING SEED-ROOTS. For stock-seed lots, hand-harvesting avoids bruising the seed-roots. When pulled they are laid crosswise of the row with the tops pointing one way to facilitate selection. The tops are cut off 1 inch above the shoulder, care being

taken not to injure the terminal bud. For bulk seed, topping can be done with a knife or by running a mowing machine over the field before digging.

STORING THE ROOTS OVER WINTER. *Pit storage.* A pit is dug, 1½ feet deep, 3–6 feet wide, and as long as needed. The roots are piled in it to a height of 1½–2 feet aboveground and covered about a foot deep with straw and earth. To avoid heating, especially during warm weather in fall, bottomless boxes 12–18 inches square, set at intervals along the top of the pile before covering, are effective ventilators. As cold weather approaches, these boxes may be filled with straw. If winter temperature remains for some time at zero or below, more dirt is placed over the pile or manure is put on after the ground starts to freeze. More protection is secured by digging the pit deeper to place most of the roots below the surface. A well-drained spot should be chosen for the pit, such as the side or top of a hill. It may be more convenient to place the pit or pits in the field where the roots are grown.

Cellar storage. In regions where the ground freezes deeply, the roots may be stored in cellars at 33–40°F. In Wyoming,[48] beet stecklings were planted on three different dates after having been out of storage for 0, 3, 6, and 9 days at each planting date. The percentages of plants surviving were the same whether the roots were planted immediately upon removal from storage or 3–6 days later. The same was true of seed yield.

Other methods. In areas with a mild winter, growers may lay the beets on the ground in long piles to a height of 12–16 inches with the tops attached. Two rows are made, with the tops outwards, and are then covered in the fall, and as the weather turns colder a plow furrow is thrown over them. In British Columbia, 4–5 inches of soil is enough coverage at the coast and 8–10 inches in the southern interior. Heating does not occur if the bulk of the roots is small.

TRANSPLANTED ROOTS. In some areas, e.g., Arizona, after the roots are harvested and graded they are transplanted to the field 6–12 inches apart in rows 3 feet apart. Transplanting is usually done in Arizona in December or early January. The transplanted crop begins to produce seedstems in early April.

ISOLATION AND PURITY. Beet varieties should be separated by 1 mile for commercial stock and by 2 miles for breeders' stock.

For a high standard of rich interior color at least 70 percent of the mature roots should conform closely to the desired type. Up to 5 percent of immature roots may be definitely off type, and up to 5 percent may show abnormal formation, e.g., splits or pronged roots. At least 90 percent of the roots should be of the desired rich color.

SELECTING ROOTS. The betanin content of fall-grown beets fluctuates in storage; the sucrose content increases for the first 2 weeks and then diminishes steadily. Hence, breeders or seedsmen who select from fall-grown roots only in the spring may be misled. The breeder aims to select mother roots that will transmit to the progeny those characteristics that give a high level of betanin (responsible for red color) and sucrose at harvest time. This objective is best attained by selecting mother roots at harvest time when these compounds are present in amounts that determine their commercial value rather than later when they have changed in storage.

PLANTING THE ROOTS. Seed-roots are planted early in the spring, commonly 1½–2 feet apart in rows 3–3½ feet apart, the smaller the roots the closer the spacing. The crown is set at its former depth, or a little lower; if the ground tends to crust, the crown must not be covered too deeply. A plant setter or transplanting machine, such as is used for tomatoes, may be used for large acreages. Someone should follow the transplanter and tamp the roots in solidly. In Europe, the roots commonly are halved or quartered much as described previously for onions.

INFLORESCENCE. The small, greenish flowers are produced in indeterminate spikes, their length and number depending partly on conditions during bloom. Therefore the main axis may be cut back in order to force the lower laterals to greater development and thus keep the plants low.

Beets need a longer period of growth than turnips in order to initiate flowerstalk primordia. In both, storage for 2–3 months at 32–40°F. facilitates fairly good development of seedstems, but beet roots develop visible flowerstalks sooner and on more roots after storage at 45–50°F. After 16–20 weeks' storage at the same temperature there is little difference between the two in rate of appearance of flowerstalks and no difference in rate of development of flowers.

During seedstem development, conditions most favorable in Michigan[213] to a high percentage of beets with seedstems are cool (less than 69.4°F.), with over 1.68 inches of rain, and cloudy (under 10.6 hours of sun per day) from May 16 until late into June. This period with these conditions, followed by a cool (less than 81.4°F.), dry (less than 1.06 inches of rain) period for July 1–15, also favors a good yield of seed.

In some areas it is the practice to remove the apical seedstem soon after the stalk appears. Removal of the center stalk allows rapid growth of the side shoots and results in more uniform maturity of seed and perhaps in slightly higher yields of seed. In fields where the apical stalk is allowed to mature, damage by lodging may be more serious.

Fruit and seed. A multiple fruit is formed by the cohesion or aggregation of two or more flowers that grow together at their bases and develop a hard, irregular, dry "seed ball." That is, the calyx continues to grow after bloom, becomes corky, and covers the seeds. The "seed" is really a fruit with 2–6 seeds. If the flower stands alone in the axil a "single-germ" seed develops. The true seed is shiny, brown, and kidney shaped.

Harvesting. Harvesting is done when the seed at the base of the stalks and branchlets is quite brown and most of the seed in the middle portion of the stalks is in the hard dough stage. The stalks are cut with a sickle and either tied in bundles or laid in small piles, the butts all pointing one way. It is usually wise to go over the field 2–3 times because the crop always matures unevenly. In rainy areas, to avoid heating, mildew, seed staining, and spoilage, the cut stalks are turned from time to time, or small bundles are made and stacked upright (sometimes on squares of canvas). Another method is to stook without tying into bundles, using a special, long wooden "horse," lower at one end, upon which to build up the stook; after the stook is made the horse is pulled out. If the seed has become rather ripe, shattering is reduced by cutting in the early morning.

Threshing and cleaning. The seed is easily threshed when fully dry, but is difficult to handle if damp and leathery. On a small scale, it can be flailed out. Homemade threshers, grain separators, or combines are used for large crops. Grain separators do the work well if the cylinder speed and wind blast are much reduced. Combines give good results when both cylinder

TABLE 1

Yield of Seed per Acre, Longevity, Minimum Required Germination, Seeds per Ounce, and Weight of Seed per Quart

	Yield of Seed per Acre, Pounds	*Seeds per Ounce* [a]	*Weight per Quart of Seed, Ounce*	*Average Longevity, Years*	*Minimum Required Germination, Percent*
Asparagus	150	1,397	32	3	70
Bean, lima	2,000	20–70	30	3	70
Bean, snap	1,600	100	30	3	70
Beet	1,900	2,006	10	4	65
Broccoli, sprouting	700	8,142	27	3	75
Brussels sprouts	900	8,477	27	4	70
Cabbage	1,000	7,725	27	4	75
Carrot	700	22,229	12	3	55
Cauliflower	150	8,621	27	4	75
Celeriac	400	50,367	18	3	55
Celery	500	76,266	18	3	55
Chard	1,500	1,503	27	4	65
Chicory (French endive)	250	20,143	15	4	65
Chinese cabbage	1,000	7,000	26	3	75
Corn, sweet	1,000	136	23	2	75
Cucumber [b]	400	1,055	18	5	80
Eggplant	—	7,238	18	4	60
Endive (broad-leaved)	300	17,318	12	5	70
Kale	—	10,331	24	4	75
Kohlrabi	—	9,197	24	3	75
Leek	200	9,905	21	2	60
Lettuce	350	26,123	14	6	80
Muskmelon [c]	250	1,086	12	5	75
New Zealand spinach	—	431	—	3	40
Okra	—	500	24	2	50
Onion [d]	600	8,543	16	1	70
Parsley	1,000	17,925	19	1	60
Parsnip	800	6,844	7½	1 [g]	60
Pea	1,800	50–230	30	3	80
Pepper	40	4,508	16	2	55
Pumpkin	300	202	9	4	75
Radish	900	3,147	24	4	75
Rutabaga	600	10,605	24	4	75
Salsify	400	2,001	9	1	75
Spinach	800	2,894	18	3	60
Squash, summer	300	380	10	4	75
Squash, winter	200	188	10	4	75
Tomato [e]	70	10,282	10	4	75
Turnip	600	13,713	11	4	80
Watermelon [f]	175	318	17	4	70

[a] From a 1943 survey of 3 samples of each kind of seed in each of 8 Canadian laboratories.
[b] About 40–50 good-sized cucumbers give a pound of seed; a fruit averages 250–300 seeds.
[c] About 30–40 muskmelons give a pound of seed; a fruit averages 400 seeds.
[d] A ton of bulbs gives 100–250 pounds of seed.
[e] Ten pounds per ton of fruit.
[f] About 6–8 watermelons give a pound of seed; a fruit averages 225 seeds.
[g] The common longevity. But parsnip seed with a moisture content of 4 percent or less may be kept in sealed containers in cold storage at 20–40°F. for at least 6 years without loss of germination capacity or seedling vigor.[27]

speed and wind blast are reduced and the concave is opened enough to avoid hulling.

Beet seed is difficult to clean. It should be run through a fanning mill several times to remove foreign material. The top screens may be round-hole zinc, size 24, 22, or 20; the lower, also zinc, may be 7, 8, or 9. A range in size is necessary because hot weather, drought, and thick stands reduce the size of seed, whereas high fertility, adequate moisture, and wide spacing increase it. Pieces of broken stems that remain with the seed can be removed by a canvas apron, set at a rather steep angle, onto which the seed is fed. The apron moves upward over rollers and carries the light sticks over the top, allowing the plump, comparatively heavy seeds to roll down the apron into a box below.

NUMBER OF SEEDS PER UNIT WEIGHT

The actual number of seeds per ounce will vary greatly between varieties of the same vegetable, owing to different growing conditions and other factors. Variation in seed weight results in a difference in the quantity of seed required per acre. Growers often plant too much or too little seed owing to inadequate data. As much as 60 percent variation in weight of seeds may occur between two varieties.[343] If the seeder is not properly adjusted for size of seed, a poor stand may result. The stand may be too thin resulting in lower yield with little or no reduction in cost per acre and thus with increased cost per unit of product harvested. Or the stand may be too thick, hence costly thinning or loss from over-crowding occurs. This is significant when labor costs prohibit the old practice of thinning with carrots, beets, and many other vegetables. Even when thinning is practiced, as with lettuce, the cost of the operation is increased if the original stand is too thick. Stand is also an important factor governing quality and economy in seedbeds where plants are grown for transplanting.

COATED (PELLETED) SEED

Coated seed weighs more than unprepared seed, and so there is less seed per unit weight. The seeds are coated with an inert material to which may be added fertilizers, stimulants, and substances to control seed- and soil-borne diseases and soil insects.

The *p*H of the coating material should be controlled. The coating is held tightly on the seed by a water-soluble, nontoxic plastic material that dissolves in contact with soil moisture.

Enough fertilizer cannot be supplied in the coating to carry a crop through to harvest, but adequate phosphorus and potash can be supplied to produce a healthy and rapid-growing seedling. It is usually not possible to add nitrogen as fertilizer because of the toxic effects, but materials like dried blood in combination with other materials that readily break down to supply nitrogen may be incorporated.

Many seeds, such as cucurbits, lettuce, and sweet corn, are fairly large and so elongated that it would be a disadvantage to coat them so as to be spherical. Such seeds are coated only enough for protection and uniformity of size and shape. Multiple-germ seed clusters, such as beet, are usually segmented before coating.

Coated seeds and special equipment make it possible to space plants more accurately and thus mechanize a crop so as to eliminate or greatly reduce the labor of blocking or thinning. Also, the control of seed rot in abnormal weather and of damping off may be enhanced. Responses from coated seed of cucumbers and melons have been good. Difficulties have arisen in coating lettuce owing to the requirement for light. Coated lettuce seed, averaging about 8,000 seeds per pound, is used commercially to some extent in California and Arizona. When sown 2 inches apart, 18 pounds are used per acre. Pelleting lima beans occasionally results in mechanical damage.

2 · PERENNIAL VEGETABLE CROPS

ASPARAGUS

Asparagus is cultivated for the tender shoots (spears) that develop in the spring from buds borne on the rhizomes (underground stems). It is a long-time crop because (*a*) it is grown for about 3 years before it is cut in quantity, and (*b*) with good care it then yields well for 10–15 years. Some of the plants might live even longer, but when a high percentage become weak it is wise to discard the planting.

Yields usually increase gradually for 6–7 years after planting. Then a rather uniform yield is maintained until about the twelfth year, after which the yield gradually declines. The best quality usually occurs from the fourth to the tenth year. Large growers should start new beds every 4–6 years so that some of their acreage is always at peak production.

The average yield per acre is about 1 ton; this includes both the early and the late years when yields are relatively low. A yield of 2 tons per acre is commonly obtained during the peak of the production period. Yields of 4 tons or more per acre often result in a subsequent lowering of production.

History and Varieties

Asparagus is native to eastern Mediterranean lands and Asia Minor. It has been known for at least 2,000 years. Purple Dutch, developed in the eighteenth century, gave rise to Argenteuil, which originated in the French town of that name about 1860; these varieties soon appeared in America. Conover's Colossal, Palmetto, and Columbian Mammoth White were introduced between 1872 and 1893.

The rust-resistant Mary Washington and Martha Washington, particularly the former, subsequently assumed the lead and have

been the basis of modern developments. *Mary Washington* is the result of a cross, by J. B. Norton, Concord, Mass., in 1910, of Mary (a female seedling selected in a bed of Reading Giant from England) and Washington (a selection from New American of unknown origin). The spears are dark green with a heavy purplish tinge towards the tip and a tightly pointed bud. Branching does not take place until the spears are well above market length. *Mary Washington 499 and 500,* developed by C. C. Hanna, University of California, resulted from nearly 20 years of intensive breeding work, and by 1949 some 10,000 acres of them had been planted in California. They have tight heads and are practically free from the purple tinge which is typical of most Mary Washington.

The leading selections from Mary Washington are classified as follows:

A. Spears overcast with purple.
1. *Paradise.* Fairly good strain but probably more susceptible to rust.
2. *Seneca Washington.* Represents progeny of a cross of male and female plants selected for yield, size of shoot, and uniformity.
3. *Viking* (Vineland 35). Derived from two selected, heavy producing plants; heavier yielding and with larger spears.
4. *Four-Way Cross.* Derived by crossing four selections.[89]

B. Spear tips almost free from purple overcast.
1. *Mary Washington 500* (California 500). Spears large with uniform, tight heads.
2. *Mary Washington 499.* Similar to 500 but slightly later and darker green.

Plant Characteristics

The underground parts consist of rhizomes or the crowns and their lateral extensions, fleshy roots, and fibrous roots. The buds are borne on the crowns, arranged in compact order on the upper surfaces. The aerial stems, which constitute the edible spears, arise from lateral buds formed the previous year on the rhizomes.

The fleshy roots arise from the crowns and may spread widely and deeply. They continue to elongate for 3–4 years and function chiefly as storage organs, and only slightly as absorbers; they store the food that is made in the leaves and stems, and give this up to the shoots in spring. New fleshy roots arise each year just behind the terminal buds of the rhizomes and replace the old fleshy roots that die.

Fibrous roots arise from the fleshy roots in great profusion. They develop in spring and summer and die in late fall, having functioned solely as absorptive organs of moisture and nutrients from the soil. Their spread is wide and deep.

The rhizomes branch and elongate a few inches each year, more rapidly in young plants than in older ones. A 15-year-old plant may have a rhizome spread of about 2 feet, and so its area of spear production does not exceed 2 feet and is usually less.

Deposits of lignin within the walls of old pericyclic fibers give strength to the spear tissue. Lignification increases with age and is greater toward the base than at the tip of the spear. Hence, the basal part of the spear is harder and tougher than the tip.

After the cutting season, the stems develop to form "fern." The cladophylls (modified stems), which perform the functions of leaves, are clustered in the axils of the true leaves. The leaves of asparagus are not like ordinary leaves but are scalelike and occur at the nodes subtending the main branches and cladophylls. Carbohydrates manufactured in summer are translocated to the fleshy roots and rhizomes.

Asparagus thrives best in regions where either cold or drought stops growth of the plant and gives it a rest. If the plant does not receive a rest the shoots become smaller each year. The low yields in the South may partly reflect the lack of cold winters. In Georgia and South Carolina the average yields per acre for a 10-year period were 25 and 39 crates, respectively, while the yields in four northern states, New Jersey, Pennsylvania, Michigan, and Illinois, were 136, 103, 99, and 89 crates, respectively.[380] Nutrition, cultural practices, and other factors no doubt contribute to these yield differences, but the temperature relations are significant. In certain regions with mild winters, asparagus can be grown well, for rainfall during the winter is low and the required rest can be induced by drought. For example, in the Sacramento Valley of California where the winters are mild and the rainfall is low, asparagus is given its needed rest by withholding irrigation water.

Raising Plants for Transplanting

Asparagus is propagated by seed which is sown ½–2 inches deep, depending on the soil moisture, in rows 1½–2½ feet

apart in a seedbed or nursery where the seedlings are grown for a year before being transplanted to a permanent site. The seed is sown early in the spring to obtain maximum growth the first year. It is sown thinly (3–4 inches apart) in the temporary rows. If it is sown thickly: (*a*) the plants develop small roots which become intertwined, making separation difficult when they are dug; (*b*) the plants are small; (*c*) thinning is necessary and must be done within a few days after the plants appear, for the small stalk may break off, and the root remaining in the ground has enough strength to send up another stalk to interfere with the growth of the other roots; (*d*) unless thinned early, the roots must be dug, thus stunting those that remain.

When sown 3–4 inches apart in rows 20–24 inches apart, 3–5 pounds of seed per acre of nursery is needed. A drill that will drop the seed at a uniform spacing and depth should be used.

The rate of germination depends on soil moisture and temperature, usually being 3–5 weeks when fresh seed is sown in early spring. Late summer or fall seeding is successful under favorable conditions, but more often it results in losses over the winter. A little radish or turnip seed, which germinates quickly, may be sown with the asparagus seed to mark the rows so that cultivation may begin before weeds outgrow the small asparagus seedlings. Since asparagus seed germinates slowly it is good practice to soak the seed for 3–4 days in warm water at a temperature of about 90°F. Soaked seed should be sown immediately after being dried sufficiently to pass through a drill.

Seed and Root Selection

Even the grower of only a few asparagus plants may wonder why, when he seemingly is giving equal care to them all, some are consistently better than others. Individual plant-performance records show wide variation in earliness, yield, size of spear, tightness of head, color, and shape of spear. Some plants produce mostly culls; others very few. Some plants start production early and continue to send up spears for a long period; others start late and send up a spear only occasionally.

The male plants often outyield the female plants 20–40 percent. These differences in yield occur because of the formation of seed by the female rather than from any genetic association between vigor and sex. Planting only male plants would result

in higher and more uniform production, but growers cannot easily separate 1-year roots on the basis of sex. The seedlings seldom bloom the first year, and so it is not possible to select for sex until the second or third year, by which time transplanting may set back, at least temporarily, any gain from the selection.

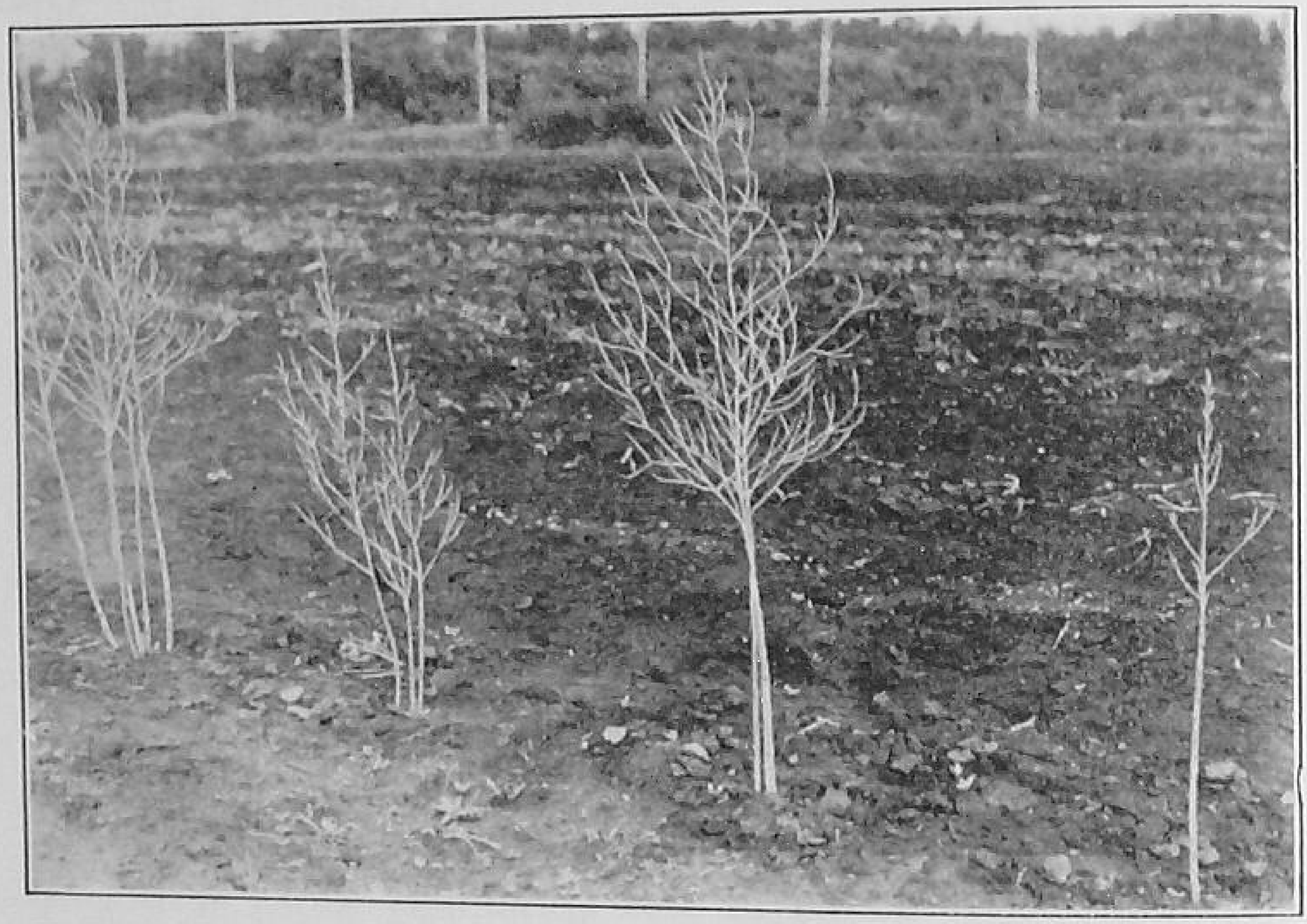

FIG. 11. These asparagus stalks have passed the cutting stage, are almost ready to bloom, and have developed some foliage. Here, as in most plantings, the number and size of spears vary in different hills.

At Vineland, Ont.,[323] plants in a mature plot of Mary Washington varied from 4 to 40 marketable spears per year. As all plants with less than 10 spears were unprofitable, 39 percent were being grown at a loss. Early-season yields showed much the same variation as yields for the whole year; in fact, the individual plants with high yields for the whole year were the plants with high early yields. Thus, selection of early plants deserves attention.

If the roots are adequately spaced in the nursery their size may indicate future performance. A good 1-year root shows a number of large, well-formed buds rather loosely distributed over the crown. The largest roots with a good distribution of buds, two or more clusters to the crown, give a new planting a quicker start than small roots. Crowns with long, spindly roots or few

roots and those with many small, pointed buds may produce plants with small spears. But if there are two lots, and in one the roots average larger, it is better to take the largest of each than to select all from the lot of larger roots. This does not mean that good, small roots should not be planted. If all the roots are small because of the season or crowding, only the poor ones should be rejected.

Permanent Asparagus Plantings

Site and Soil

Because asparagus is a long-lived crop it is wise to select a site that will be suitable over a period of years. It is not wise to replant asparagus on land that previously produced this crop, owing to a toxic reaction.

Asparagus grows naturally near salty marshes and where the soil reaction is neutral or slightly alkaline, but it thrives well on soil with a *p*H as low as 5.0. Salt was once thought to be essential and, in moderate amounts, will not harm asparagus. It is now applied by few large growers, except as in ordinary fertilizers.

Sandy loams and other light soils that warm readily result in an early crop but the plants are shorter-lived than on heavier, deep, rich, well-drained soils. Much asparagus is grown on muck land. Heavy soils warm slowly in spring, are hard to manage, may drain poorly, may bake and prevent proper root penetration, produce many crooked, coarse spears, and develop poor storage roots. On soils with a high water table the crowns may rot or may grow toward the surface, and injury by freezing may result.

Little financial return is realized during the first 3 years, and so the condition of the land should be such that necessary cultural operations are reduced to a minimum. Soil preparation should start a year or more before planting.

Manure and Fertilizer

A 2,000-pound crop removes from the soil about 2 pounds of nitrogen, 5 pounds of potash, and 2 pounds of phosphorus. A crop is harvested each year, and production continues for years. It might seem that only enough fertilizer need be applied to

return to the soil these amounts and to compensate for the tops removed from the field, but much greater amounts are usually essential.

Manure is expensive and may be difficult to obtain; otherwise it may be added freely. Since asparagus is a comparatively long-lived crop it is important to build up a good supply of organic matter in the soil before planting.

Advantages result from an application of about 1,500 pounds per acre of a fertilizer, such as 2-12-10, in the bottom of the planting furrows. This fertilizer is covered with an inch or two of soil before setting the plants. By this method much needed phosphate and potash is added to the lower soil layers. Deep placement of fertilizers is not practical after the crop is established, nor is deep plowing or cultivation.

If manure must be omitted, as is often the case, ½–1 ton of a complete fertilizer can be applied to advantage in established plantings. The fertilizer is often applied at two different times, half before the cutting season begins and half at the end of it.

The spears derive their nutrients largely from the food manufactured the previous year and stored in the fleshy roots. Since the "plant food" needs are high between the last cutting and autumn, the use of fertilizer soon after the last cutting often stimulates growth and aids the plants in storing a reserve for the next year's crop. In order that the buds may produce first-grade spears, there must be abundant food reserves back of them. The fertilizer program must be developed to supply a high level of organic food reserves for the succeeding season.

It should be borne in mind, too, that the plants can take in and use fertilizer early in the spring, before there is any top growth. Furthermore, a dry spell may occur after the cutting season, and if fertilizer is not applied until then it may not go down promptly to the feeding roots where it can be absorbed. If the brush remains dark green until frozen in the fall, it may not be so important to apply fertilizer early in the spring. If the plants become yellow or mature early in the fall, nitrogen especially is needed; if it is applied the next spring, it usually stimulates the growth of spears. The roots can assimilate nitrates even though asparagus during the cutting season has practically no aerial organs.

The fibrous roots are the chief organs involved in the transformation of nitrates to organic nitrogen. Within the fibrous roots nitrates are reduced to nitrites and ammonia, then there is an increase in asparagine and amino acids. Accompanying nitrate assimilation in darkness the loss of carbohydrates is much in excess of that occurring in like plants also grown in darkness but with no external nitrogen supply. The assimilation of nitrates in darkness by plants not already high in organic nitrogen and containing abundant carbohydrate material in the storage roots results in a larger yield of spears because of an increase in their size. Good top growth occurs following nitrate assimilation in darkness, together with the associated increase in yield of spears when cutting is stopped and the plants moved to light before carbohydrate material of the roots is depleted. The plants continue to assimilate nitrates in darkness until available carbohydrates are exhausted and death ensues, though similar plants with no external supply during the same period show no sign of death. At 48°F. the transformation of nitrates to organic nitrogen takes place slowly, and at much below this temperature, probably not at all. At 60–84°F. the assimilation of nitrates is rather rapid. The storage roots and *actively growing* tops apparently may, but rather seldom have the opportunity to, assimilate nitrates because nitrates are transformed to organic nitrogen in the fibrous roots before reaching other organs of the plant. But at 50°F. or lower, nitrates may be translocated to all parts of the plant. Later, with a rise in temperature, nitrates are rapidly assimilated by and disappear from the storage roots and actively growing tops and are found in and assimilated by only the fibrous roots.[289]

Age and Care of Plants for Planting

One-year plants are best for planting. In New Jersey,[337] vigorous 1-year plants may have 18 storage roots with a combined total length of 51.8 feet; a 3-year plant may have 115 storage roots with a total length of 125.6 feet. Obviously, the root systems of 2- or 3-year plants are mutilated much more than the 1-year roots in digging.

Dividing crowns is less satisfactory than raising plants from seed. A 3-year root is too large to handle, except for small areas, and even a 2-year root cannot be dug without some permanent damage. One possible advantage in favor of the older plants is that the sexes may be separated more readily, as was discussed previously. Plants grown from seed in nursery rows for 1 year and then moved to the field are usually superior to plants from seed sown directly in the field.

A herbicide (see Pentachlorophenol and Dinitro, Chapter 15) may be useful in the seedling bed.

The plants can be turned up from the soil with a moldboard plow and pulled up with a potato hook, or a special U-shaped

knife can be used to lift them. A potato digger will lift the plants and shake them free from most of the soil. This method makes the separation of the plants easier and reduces mechanical injury that occurs from the plow and potato hook.

Time of Planting

In parts of the South and in the Delta and Imperial Valley districts of California, the roots are set in fall or winter. Spring planting is the leading practice in the North. The deep furrows left from fall planting usually fill up, and as a result many plants may be smothered and fail to start growth.

Depth of Planting

The tendency is to set the crowns shallower than formerly. On a light soil, a 6- to 8-inch depth is desirable; on a heavy soil, about 4–6 inches. Shallow planting promotes more vigorous growth and a large, early yield, as the soil warms up more quickly near the surface. The crowns seldom come closer to the surface than if they had been set deeper, unless the soil is cold and the water table is high. Some think that shallow-set plants are short lived and that the crowns may be injured by deep discing, but, if well cared for, the planting should last as long as a deeper-set one. If, however, plantings are too shallow on light soils, the crowns are soon exposed through wind erosion. If the crowns are well below the surface it is sometimes possible to cultivate the ground and work in manure without injuring them.

Spacing the Plants

Crowded plants produce an inferior crop, both in size and in quality, and reduce the productive life of the bed. Good commercial spacing is 1½–2 feet apart in rows 4–6 feet apart. Closer spacing may give higher yields only during the early life of the bed. Spacing 5 × 2 feet requires 4,356 plants per acre.

Setting the Plants

Deep furrows can be opened by plowing both ways in one furrow. The plants are set in the furrows, and the crowns are immediately covered with 2–3 inches of soil. When growth begins, soil can be filled into the furrow and more added at

intervals by cultivation to control weeds until the furrow is entirely closed. If all the soil is placed over the crowns immediately after they are set, the slower-growing plants may be smothered.

Annual Crops between Rows

During the first year annual crops, such as lettuce, early cabbage, peas, beet, beans, radish, or other cultivated crops, can be grown between the rows. Such crops should not be allowed to interfere with the growth of the asparagus.

Cultivation and Weed Control

A heavy crop of weeds may take much of the fertilizer that is applied. It is fully as important to kill the weeds as it is to apply fertilizer. Pre-emergence weed control is becoming a regular practice. (See also Chapter 15.)

Cyanamid, broadcast at the rate of 300 pounds per acre early in the spring, and 100 pounds after the cutting season, when the weeds are wet with dew or rain, finds some favor as a nitrogen fertilizer for its calcium content and as a control for certain broad-leaved weeds, including chickweed.

Some formulations of 2,4-D deform the spears that are hit but the rest are not affected. It can safely be used on broad-leaved weeds sometime before or after harvest but if applied in the cutting period some of the crop is lost. When applied on the soil before weeds germinate, it materially reduces the weed growth including annual grasses and chickweed.

When cutting ceases, the disc harrow, if not run deep enough to injure the buds, may be used to level the field and destroy small weeds. When the top growth is about 2 weeks old, a ridger or a small plow may be used to throw a light furrow from each side among the stalks, to smother small weeds and to help support the foliage that grows later.

Irrigation

In irrigated districts, the first irrigation is given 1–2 weeks after harvesting begins. A second application is given at the end of the harvest season and after the planting has been manured and disced. In a dry year, a third irrigation may be needed

in late summer. A final irrigation is sometimes given just before freeze-up.

The shallow furrows which guide the water between the rows of plants are made by lightly cultivating the soil and then working it toward the plants. Good procedure is to flush the water rapidly down the rows and then reduce the streams in the furrows to a slow trickle and let them run for several hours. This permits the soil to soak up a maximum amount of water and the irrigation of the rows to be finished simultaneously. Cultivating as soon as the top soil is dry enough to be worked keeps the soil from baking into a hard crust, checks weed growth, which is very rapid on irrigated land, and helps aerate the soil.

In the Delta area in California,[154] most fields are subirrigated. Usually 1–2 irrigations are made in the cutting season and 1–2 in summer. On heavy soils that do not subirrigate easily, surface irrigation is done in furrows between the rows, usually one furrow every other row. On lighter soils, surface irrigation may be used to leach alkali out of the upper soil. In the San Fernando and Imperial Valleys one surface irrigation is practiced. Irrigations should be frequent enough to maintain available moisture in the root zone during the growing season. Winter flooding (December or January) is general on the older beds in the Delta. Levees are made around the field, so that it can be flooded 6–12 inches deep for 4–6 weeks. Usually a few rows of asparagus are left with the tops uncut, next to the levee, to check wave action, and the levee is further protected by a thick lining of matted fern. In January or early February, the water is drained off. When the field is dry enough, the between-row centers are worked and a small ridge is made over each row.

Fields flooded in winter start to produce 10–14 days earlier than unflooded fields in California. Growth starts at 59°F. when abundant moisture is present, but the plants remain dormant at 63°F. when the soil is barely moist. There is apparently no harmful effect, e.g., shorter life of bed, from flooding.

Removal and Disposal of Tops

Food which is manufactured in the tops of the plants is transported to the roots for use in the coming spring. It continues to move to the roots until the tops die or the cladophylls drop. Removal of the tops too early reduces the crop the next year.

They provide much valuable organic matter when disced into the soil. If rust is present it may be wise to remove and burn the tops as soon as they die after harvest.

Harvesting

In cutting, one must consider: (*a*) the age of a new planting at which to begin cutting; (*b*) the optimum cutting period for a new planting; (*c*) the cutting period for an established planting that gives the best yield year after year. The object is to harvest or cut only as much as will not exhaust the plants. Even with rich soil and adequate moisture the plants in their weakened condition lack time to regain normal strength if cut beyond the safe limit. This is a common cause of a good planting suddenly dropping in yield. Sometimes a light cutting, not more than 2 weeks, can be made in the second year. In the third year cutting is done for about a month, and in later years for about 8 weeks. The cutting period of a young planting can be gaged by the growth of the tops in the previous year. Cutting should be stopped in time to allow the plants to develop strong vigorous tops which will manufacture and store adequate food in the roots for the production of future crops of spears.

Cutting the spears. The usual method of harvesting is to cut the spears 1–1½ inches below the surface of the soil with a special, long-handled knife with a double or V-shaped point or with a slanting cutting edge. A good guide is to cut half as deep as the top of the crown is below ground; e.g., if the crown is 4 inches down, the spears are cut 2 inches below the surface. Some white butt accompanies the green portion and helps to keep the product fresh longer, but the lignified, basal part is tough and commonly is discarded later. The spears are usually cut when they protrude 6–9 inches aboveground (slightly longer in shipping areas). Canning factories may specify certain lengths and sizes for their grade regulations.

The cutter avoids many of the young spears and buds by placing the knife near the spear to be harvested and pushing the knife straight down to the necessary depth. If the spear is held and gently pulled with the hand, it will cut easily, and the operator will know when it is loose. One well-directed thrust suffices. A beginner may jab several times before he succeeds in

severing the spear; in doing so he wastes time and energy and injures other spears and crown buds.

Frequency of cutting depends on the growth made by the spears. During warm weather asparagus may grow 6–10 inches

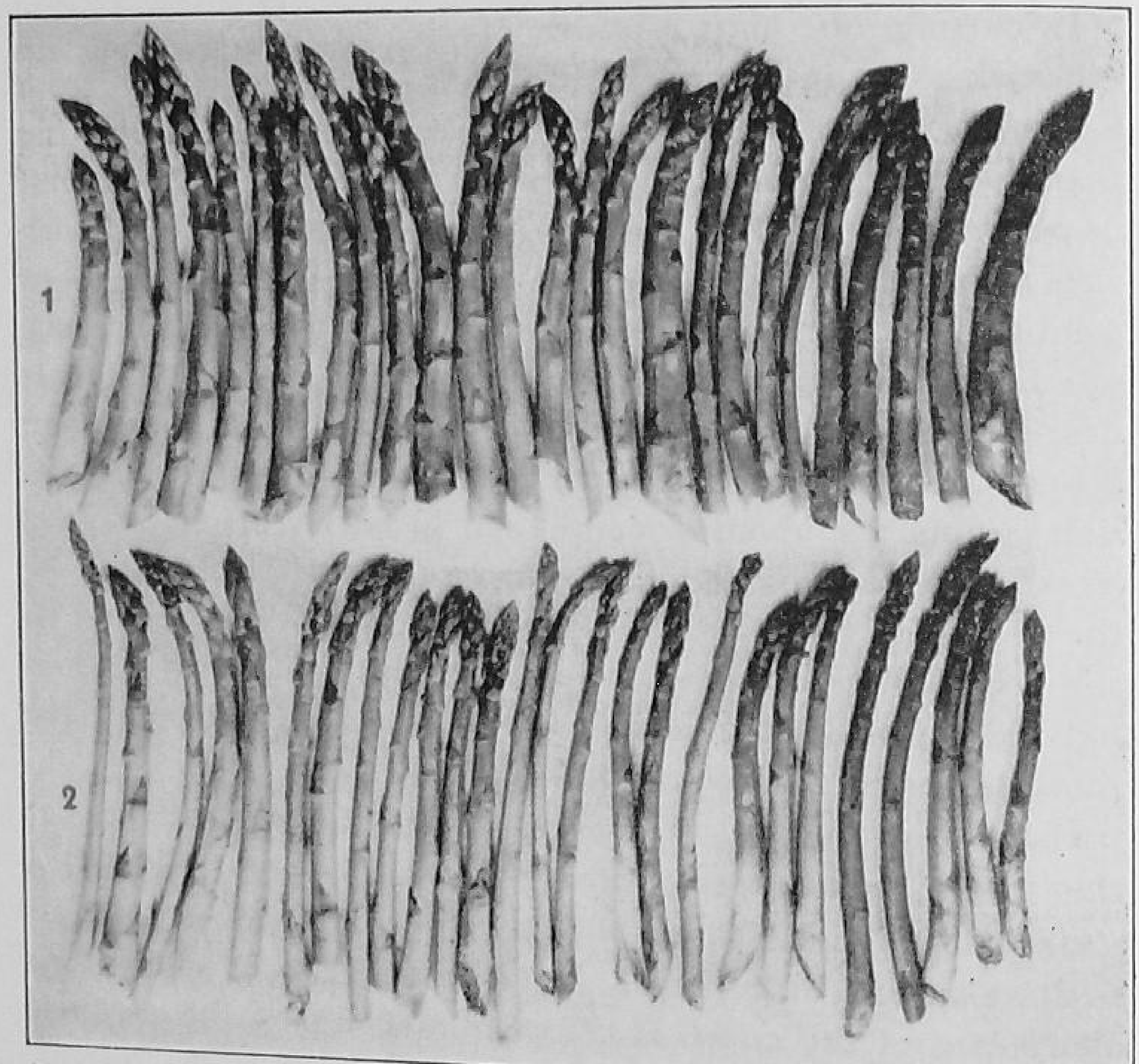

FIG. 12. Spears in Row 1 from plants harvested yearly until June 15; spears in Row 2 harvested yearly until July 15; photo taken June 15. This illustration shows the effect on diameter of spears when plants are cut too late year after year. (*Courtesy Dr. E. S. Haber, Iowa State College.*)

in 24 hours. The higher the temperature, the closer to the ground the spears will begin to branch. The head or tip should be tight. In warm periods, growth is very rapid and cutting daily, or even twice daily, may be necessary. At other times, cutting every other day or, early in the season, every third day may suffice. All spears ready for harvesting should be cut whether needed or not.

SNAPPING. The spears may be broken with the pressure (a brisk push) applied at a point not far below the tip. Holding

between the thumb and fingers is best. If the spear is grasped with the hand farther down, e.g., snapped at ground level, the break may come below the point where the fiber begins to get tough. Harvesting by snapping is quicker and cheaper, the butts are left in the field, and in most respects it compares favorably with cutting, particularly for canning.[16]

Side branching occurs only on stubs that are less than ½ inch in diameter, and it may be wise to cut these off occasionally. Bleeding from the stubs results in little loss of food material or mineral nutrients from the plants.

Snapped asparagus is more succulent, has a higher rate of respiration, and loses weight more rapidly than cut asparagus. Also, in a short time the cut ends dry and fiber development occurs in snapped spears. To insure a quality product, snapped spears should be canned within 8 hours of harvest.[61] In California, snapping has resulted in 13 percent lower yield than cutting.

Preparing for Market

There is a rapid reduction of sugar content and an increase in fiber the first 24 hours after harvesting. High temperature, sun, and excessive drying cause asparagus to wilt and lose palatability. At the packing shed, the spears are trimmed and set upright in a cool place in a shallow pan of water, or on wet moss. If soil must be removed from the butt end, the spears should be doused in water, butt down, with care not to wet the tips.

The two types of western packs are the loose and the bunch.[154] The smaller grades are usually put in loose pack. After trimming to 9 inches long, the spears are put in a pyramid crate, on the bottom and two sides of which oiled or waxed paper has been placed. On the paper at the bottom is laid a layer of wet moss. During packing the crate rests on its side. To make handling easier, a tin sheet is placed on top of the wet moss. The butts of the spears are placed against the tin sheet; and when the crate is filled the sheet is pulled out, leaving the butts of the spears on the wet moss. The oiled paper is then folded over the open side, and the side and top slats of the crate are nailed on. Crates are packed with a bulge, so that if wilting occurs the pack will remain tight.

For the bunch pack, grading is done by hand on the basis of diameter of spear. The different grades are tied in bunches of 2½ pounds each (1-pound bunches are coming into favor). The spears are squeezed together in the bunch with a lever and tied securely with ¼-inch tape. If the spears are slightly wilted, a tighter pack can be obtained, for they later absorb water from the moss in the crates and regain their turgidity. After tying, the bunches are trimmed to 9 inches long with a large knife or circular power knife. They are then placed upright with the butts in a pan of cold water 3–4 inches deep, to remain until packed. For packing, they are wrapped in special paper and placed in the crate, with the butts on the wet moss. Top and side boards are nailed on. Most California bunch asparagus is shipped in two-compartment standard-sized pyramid crates.

Storage

The growing shoot is physiologically one of the most active organs of the plant. At 34°F. the heat production of asparagus is about 7 times that of the apple. But at 32°F. growth of the spears, which takes place at higher temperatures, is practically nil, and the original tenderness, which at ordinary storeroom temperatures is lost soon after cutting owing to the formation of woody tissue, is preserved for 3–4 weeks. Also, although the sugar content, to which asparagus owes some of its flavor, diminishes rapidly at higher temperatures, it remains much the same as when the asparagus is cut if the stalks are stored promptly. Loss of water in storage or transit may be great if the spears are not kept moist at the base. When the base is kept moist the stalks commonly gain in weight in storage. After a long haul to market, asparagus will not keep in storage for more than 3–6 days. Recommended relative humidity is 90–95 percent. The average freezing point is 29.8°F.

White Asparagus

White or blanched asparagus is grown by hilling soil over the rows so that spears of desired length are kept from light. The rows are set farther apart than for green asparagus so that soil can be ridged over the row without plowing too deeply. Hilling begins in early spring and continues during the cutting season

as needed. White asparagus is cut below the surface of the soil just after the tip emerges. After harvest the ridges are leveled down. Most of the white asparagus produced in America is grown on the peat soil in the Delta district of California. Green asparagus is higher than white in food value.

Insect and Disease Control

The dark-gray, sluglike larvae of the *common asparagus beetle* (blue black with orange markings) feed on the foliage; the larvae of the *twelve-spotted asparagus beetle* feed on the berries. Controls are: during the early cutting season, dusting with rotenone; after cutting is over, dusting or spraying with an arsenical; cleaning up and burning all rubbish to destroy the overwintering stage.

Rust: reddish pustules appear on the stems and needles of susceptible varieties in midsummer and turn dark in autumn. The brush becomes yellowish as if ripening prematurely. Plantings should be started with seed of a dependable Washington strain whose resistance has been established.

Fusarium stem rot or *wilt* is worse on light, sandy soils, and during years when the soil temperature is abnormally high. Affected plants turn yellow, wilt, and dry up. Controls are: do not start a seedbed, nursery, or planting on or near old asparagus land within 4–5 years; do not use roots from an old asparagus bed; avoid wetting the soil above the crown in irrigating.

RHUBARB

Rhubarb, or pieplant, is a perennial which comes very early in the spring. The leafstalk (petiole) is the edible part.

In areas with dry summers and mild winters, rhubarb rests in summer and grows during winter and early spring. In colder areas, the plant rests in winter and produces its best crop in the cool spring weather. Its commercial culture is mostly limited to areas where the summers are humid and the winters are cold enough to freeze the ground at least 3–4 inches deep. The underground portion is very hardy, but the leaf portion cannot tolerate temperatures below 25°F. without damage to the crop for several pullings.

History

Rhubarb has been known since about 2700 B.C. The knowledge of its healthful properties spread westward from China to Arabia, thence through the Near East to Europe.

The first part of the word rhubarb refers to this plant as from the region of the Rha River (now the Volga). The second part means that the plant came from the barbarian district beyond the immediate confines of the Roman Empire.

Varieties

Most of the best varieties are of Canadian origination, e.g., Macdonald (Macdonald College, Que.), Valentine (Horticultural Station, Vineland, Ont.), and Early Sunrise (Experimental Station, Kentville, N. S.). Some others are Victoria, Sutton's Seedless, Riverside Giant, and Linnaeus. The name "Strawberry" really refers to a type (color) rather than to a distinct variety.

Producing Rhubarb

Soil and Fertilizer

Rhubarb is a very strong feeder and needs much moisture. Usually, the richer the soil, the better the results. A good plan is to summer-fallow the land the year before planting to aid subsequently in weed control; manure may be worked in before the summer fallow. Fibrous material high in "plant food" should be well worked into the soil, but fresh manure should not be in direct contact with the crown or roots. Root rot or poor root development often may be traced to the caustic action of manure or to the air spaces around the roots caused by coarse, strawy substances.

The planting should be heavily topdressed with manure, either soon after harvest or in the autumn. The manure may be supplemented with a fertilizer applied both in spring and after harvest. A good plan is to apply a fertilizer high in nitrogen content in the spring, and again soon after harvest. There should be enough "plant food" available after harvest to enable the plant to store a reserve in its roots for the next crop.

PROPAGATION. Pieces for planting are obtained by dividing the crowns while dormant in fall or early spring. A fair-sized piece of rhizome with 2–4 buds gives quicker results than single-bud pieces. With old plants, only the sturdy outer portions should be used, and the center should be discarded.

PLANTING. If planting is done in spring, the plants are set while dormant or nearly so. Fall planting is often better. Early fall allows time for the development of fresh roots and establishment of the plants, but planting can also be done later, even in very late fall. Rhubarb roots are much like peony roots in re-establishing themselves quickly during the cool fall days.

A furrow is made, or holes are dug, wide enough to accommodate the roots and deep enough so that the top buds are placed about 2–3 inches underground; the bud scales should just show. If set too deeply, the buds may decay. The soil is firmed around the roots, but the top few inches are left loose. Damaged and long whippy roots are cut back before planting. If the roots are planted behind a plow they are cut to a uniform length beforehand.

SPACING. The usual spacing is 3–5 feet each way. Best spacing depends upon such factors as area involved, method of cultivation, and variety.

MOISTURE CONSERVATION

The root system of rhubarb extends in the soil 3–4 feet laterally and to a considerable depth, filling the surface layer with fine absorbing roots; consequently tillage should be shallow.

The large leaves use much water, and so moisture conservation is significant. Soon after the ground freezes it is wise to cover it with strawy manure. Another plan is to hill the rows with a plow and then to apply a light manure mulch. These ridges are leveled in early spring, and the manure is worked in the soil. Often manure is applied to the rows in early spring or soon after the ridges are worked down. Before the very hot, dry weather of midsummer, 2–3 inches of well-rotted manure may be mulched around the plants (not on the crowns). The next spring this is lightly worked into the soil, and more mulch is again applied in midsummer.

Irrigation

Rhubarb will usually do well with three irrigations, one in early summer, one in midsummer, and one in late autumn just before freeze-up. Extra irrigations are often beneficial if the water does not lie. The water should run until it has soaked well into the soil.

Seedstems

Any factor that interrupts steady growth may cause bolting. Poor varieties, impoverished soil, drought, heat, and long days are significant factors. Seedstems should be removed as soon as they form, because seed bearing weakens the plants, reduces the number and quality of stalks, and results in fewer active buds or eyes.

Pulling (Harvesting)

No stalks should be pulled until the second year and but few until the third. The first harvest should not exceed 3–5 weeks. Later harvests may be for 6–8 weeks if size of stalk continues good. If harvested too long the plant lacks sufficient time to store enough reserve food in its rhizomes.

The stalks should be pulled out, not cut. Cutting or breaking off the stalks makes open wounds which encourage disease. The stalks are easily harvested by grasping them near the base and pulling and twisting to one side in the direction of growth. They are grasped with the thumb and last three fingers, and the forefinger is thrust down along the inside of the stalk below the surface of the soil in order to avoid breakage. Immediately after pulling, the leaf blades should be severed, leaving 1–2 inches of midribs with intervening tissues. Pulled stalks are kept out of the sun and wind to avoid wilting.

Pulling all properly usable stalks from each hill allows new growth to develop for another harvest 7–10 days later and gives a greater yield than indiscriminate work. No plant should be stripped of all its stalks, and after harvest the plants should continue to grow vigorously and produce leaves freely to provide abundant reserve food in the fleshy root before winter. A heavy crop in any year depends on a strong leaf growth the year before, on moisture, and especially on the reserve food stored in

the roots or crowns over winter. Too prolonged harvesting is unwise. But just before a severe frost in the fall, thrifty stalks may be harvested without adverse effect to the plants.

A good yield is 2 tons or 20,000 stalks per acre. The commercial age of a planting is about 5–7 years, and so the grower has returns for 3–5 years.

Storage

Rhubarb stalks, if fresh and in good condition, may be stored 2–3 weeks at 32°F. and 90–95 percent relative humidity. The bunches are packed in crates which are stacked to allow ample air circulation on all sides; otherwise there is danger of heating and mold growth. Rhubarb freezes at 28.4°F. in storage.

Producing Early Outdoor Rhubarb

Earlier rhubarb is secured by placing nail kegs, small barrels, or boxes open at both ends over the clumps in very early spring, and surrounding them with fresh, unfermented horse manure. Burlap bags or other materials may be used for covers. Heating takes place, as in a hotbed, and forces rapid growth of stalks with slight development of the blades. Later, the covering is removed, and the plants are allowed to develop naturally. Another plan is to place loose, strawy manure over each hill when growth has started. The mulch partially excludes light, protects the stalks against late frosts, and promotes an early crop.

Indoor Forcing

The chief method of forcing involves excluding practically all light and results in pale or pinkish stalks and little development of foliage. Near Detroit, Mich., and Montreal, Que., great rhubarb-forcing industries have been developed, most growers using crude buildings and hot-water heat.

For forcing, 2–3 year roots are best. Older roots often give a light yield. The crowns to be forced are dug before the ground freezes and moved to a conveniently accessible place. They are left outside until they have frozen or have been exposed to severe frost, but they are covered with a little soil or straw, to prevent loss of water by evaporation, for some time before being brought indoors.

Freezing at 20°F., followed by a rest for 3–4 weeks at 30°F., is an effective treatment if temperatures can be controlled. Then, a common forcing temperature is 45–55°F. When forced at 50°F. and bottom heat of 55–60°F. rhubarb will give an increased total yield and produce a greater percentage of the total yield early. Excessive bottom heat may reduce the percentage of fancy grade. The first harvest is ready 4–5 weeks after forcing starts. Pulling may continue 3–4 weeks, or until the roots are exhausted. New lots may be forced at intervals, e.g., of 3–4 weeks.

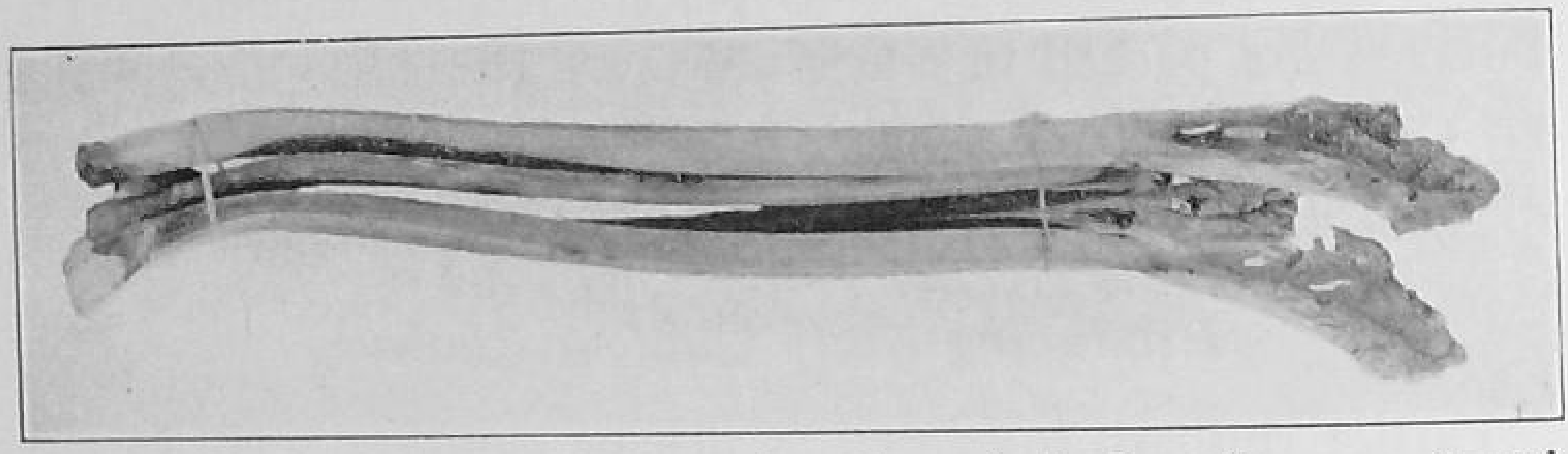

FIG. 13. The small leaves indicate that these rhubarb stalks were forced in darkness.

Conditions that cause failure in forcing rhubarb in winter are: selection of unsuitable crowns; failure to expose the crowns to sufficient cold before forcing; planting in too dry or too hot a place; and exposure to bright light. Crowns that previously have been too severely stripped of their leaves and stalks are too weak for forcing because there is little reserve or stored food in the roots. The crowns should not be forced again for several years, if at all.

Insect and Disease Control

The *rhubarb curculio* beetle eats holes in the stems and larger leaf veins. Gum usually exudes from these holes, and in most cases the affected area dries out and turns brown, although occasionally rot sets in; the stems break easily. Control is hand-picking and eliminating dock plants on which the insect breeds.

Crown rot appears as sunken brown spots at the base of the leafstalk. The spot enlarges rapidly and the leaf wilts. The rot may spread from stalk to stalk until the entire plant is killed. Controls are: digging out and burning diseased plants, without scattering infested soil; disinfecting soil where the plant stood,

with formaldehyde 1-50; dipping roots in corrosive sublimate (1-1,000) or formaldehyde (1-240); and discarding roots that are discolored inside. Spraying well into the crown of the plant with Bordeaux mixture may aid in control but causes unsightly spotting of the stalks if applied before harvest.

Leaf spot shows as irregular circular spots with white centers surrounded by a red band bordered by light green. The centers may crack and fall out. Control is removing and burning the old leaves and stalks in late fall, after frost, and spraying the plants with Bordeaux mixture in spring when growth starts.

HORSERADISH

Horseradish is a hardy, tenacious perennial, but it should be treated as an annual. A common practice is to consign horseradish to a neglected corner of the garden, where it struggles for existence and produces inferior roots. There, the plants may spread badly and become a nuisance. Horseradish is more readily kept localized if it is planted on a slant in a prepared long mound of soil, rather than in a flat surface row. But it is wise to remove the plants every year and to take out all the roots, as otherwise the plants spread, grow close together, and do not produce high-grade roots. Horseradish is grown commercially on level ground, as outlined later, near St. Louis, in Illinois, and at some other centers for the manufacturing trade.

Horseradish is grown for its pungent roots, which are grated, mixed with salt and vinegar, and eaten as a relish, condiment, or appetizer with meats, oysters, and other foods. The pungency is due to the presence of an allyl isothiocyanate (C_2H_5CNS) and a butyl thiocyanate (C_4H_9CNS), similar to the mustard oils, occurring in combination with the glucoside sinigrin.

History

Horseradish is native to regions from the Caspian Sea to Finland. It is the *Armoracia* of the Romans. The German name *meerrettich*, sea radish, associates horseradish with proximity to the sea. Japanese horseradish (*Eutrema*) is an entirely different plant.

The "horse" in horseradish refers to hoarse or coarse, rather than to the animal. Thus horseradish is the coarse radish.

Plant Characteristics

There are two types of horseradish, the "common" and the Bohemian (Maliner Kren or Bayersdorf, imported from Austria by the U. S. Department of Agriculture in 1899). The "common" is a broad-leaved, hollow-petioled type and comprises nearly all the commercial acreage. The roots are corky-tan and white within. The Bohemian is a smooth, narrow-leaved, solid-petioled type. It lacks root quality and yield but is comparatively resistant to white rust and mosaic.

The plant blooms freely but is highly sterile. Seedlings have been raised from a cross of the "common" and Bohemian types.[409]

There is little choice of variety. But care should be taken to obtain good, healthy planting stock of a strain that is already giving good results in the region where it is to be grown.

Producing Horseradish

Soil

River bottom soils and light sandy loams produce desirably long, straight roots. Heavy or shallow soils may cause rough, prongy roots which give much waste in preparation for use. The soil should be plowed deeply and pulverized thoroughly before planting.

Propagation

Cuttings, or sets, are pieces of roots ¼–½ inch thick and 5–14 inches long, or ½–1 × 1–2 inches. No effort is made to arrange the small sets in the row as is done with the longer sets. The sets are usually made from side roots which are trimmed off in preparing roots for market. The longer sets are better whenever lifting or stripping is practiced, since growth of the main roots is the objective, and these increase in diameter only. The longer sets are made square at the top and oblique at the bottom to indicate which end to place downwards when planting. They are then bunched, packed in sand, and stored in a cool, moist cellar, or placed in a well-drained pit, until planted.

In propagating by crowns, a portion of the old plant, consisting of a piece of root and crown buds, is merely lifted and placed

in the new location. Pieces of roots and crowns remaining in the soil are usually enough to re-establish the plants.

Planting

Planting is done in early spring or in the fall. The sets are placed 1–4 inches deep and 1–2 feet apart in rows 2½–3 feet apart. Sets may also be placed at an angle with their tops near the soil surface in a furrow 4–5 inches deep. Soil is firmed around the sets. They usually make good roots the first year.

Cultivation, Manure, and Fertilizer

Thorough cultivation should be given throughout the season, and it should be borne in mind that the crop makes its most rapid growth during late summer.

Manure, unless very well rotted, should not be applied in the spring of the year that the horseradish is planted or it may cause excessive growth of tops and irregular branching of roots. Horseradish roots tend to go deep; therefore, manure and fertilizer should be worked rather deep into the soil.

Lifting and Stripping the Sets

Roots may be dug as needed, but this is not necessarily the best procedure. A good plan is to clear the whole bed at once and store the roots in sand until wanted. This plan should be repeated each year, and a new site ought always to be used for the crop, because of the strong tendency to spread.

Commercially, the roots are lifted once or twice during the year, first when the largest leaves are 8–10 inches long. The soil is removed, without disturbing the roots at the lower end of the set. The crown end of the set is then raised, and all but the best sprouts or crown of leaves removed. Any small roots at the top or on the sides of the set are rubbed off, leaving only those at the bottom. The set is then returned to its position, and the soil is replaced. About 6 weeks later this procedure is repeated. It promotes better roots and, if done early in the season, does not greatly check the plants. Woolen gloves protect the hands in rubbing off the small roots. Stripping the roots may not increase yields any more than enough to offset the cost of lifting, but it results in more straight roots of good size which bring a market premium.

Harvesting and Storage

Since horseradish makes its greatest growth late in the season, harvesting is delayed as late as practicable. The roots are dug in the fall even though they are winter hardy. They are removed completely to prevent a volunteer crop the next year. Side roots are trimmed off, and the larger roots are packed in bulk for shipment or tied in bunches of 6–8 for special trade. Marketable yields are 2–4 tons per acre. Plants grown 2 years yield higher, but the roots are woody and inferior in quality.

Horseradish stores well for 4–6 months at 32°F. and 90–95 percent relative humidity. Care must be taken to prevent withering. The roots should not be kept exposed to the light, or they will turn green. The freezing point in storage is 26.4°F.

Preparation for Use

Horseradish is prepared by cleaning and grating the roots directly into white or distilled vinegar of 4½–5 percent acid content. Cider vinegar will turn the grated horseradish dark.

Insect and Disease Control

Leaf diseases, such as *white rust* and *leaf spots,* are controlled by burning all the old infected tops. Volunteer horseradish near commercial plantings should be destroyed because some leaf diseases, including *virus* troubles, overwinter on such plants. Close planting should be avoided and weeds should be eradicated, to facilitate drying of the leaves after rains and dews.

Wilt and *root rots* are difficult to control. Infected specimens should be discarded before they are pitted and again before planting in spring. After sets are selected for pitting, they should be dusted with sulfur. Roots should not be pitted in the same location year after year (storage cellars should be disinfected).

3 · CORN CROPS

SWEET CORN

Sweet corn is distinguished from other corns by its high sugar content when in the milk and early dough stage and by its wrinkled, translucent kernels when dry. The only genetic difference between sweet corn and field corn kernels is a single recessive factor or gene which makes the sugary condition of the kernel persist in sweet corn; it prevents the conversion of some of the sugar into starch.

History

Corn and the Indians. When the Indians are credited with growing corn from ancient times on this continent, the reference is properly to maize or field corn, not sweet corn. Field corn was widely used by them for "roasting ears." Sweet corn is probably a mutant of field corn of post-Columbian origin, and mutants which met with favor among the settlers appeared in New England in the nineteenth century.[125, 126]

Origination. Pod corn, a type with each kernel covered in an individual husk, is probably the ancestor of cultivated corn. Homozygous pod corn is often an earless, perfect-flowered plant that bears its seeds in the terminal inflorescence or tassel. It possesses the two essential characteristics that maize now lacks and that it needed to survive in the wild, namely, a protection for the individual seed (prominent glumes) and a means of dispersal (a brittle rachis).

Corn probably had its native habitat, and was first used, in the lowlands of South America "back of the Andes," in the forests interspersed with rainy, green savannas, where abundant rain is followed by a dry period. A number of references associate pod corn with the Guerany Indians of South America. One

of these describes a corn which bears seeds in the tassel and which may have been the homozygous, earless form of pod corn. Pod corn is represented in prehistoric Peruvian pottery.

Prehistoric maize remains were uncovered in 1948 from the accumulated refuse of an abandoned cave known as Bat Cave, located in Catron County, New Mexico. This refuse represents a period beginning about 2500 B.C. and ending at about 500 A.D. to 1000 A.D. From a study of the material it is concluded [253] that: (*a*) primitive maize was both a pod corn and a pop corn; (*b*) maize did not originate from teosinte; (*c*) maize has been strongly modified in the later stages of its evolution by an introgression of teosinte (or *Tripsacum*) germ plasm.

The change from pod to naked corn is due to a recessive single gene mutation which occurred under domestication and immediately acquired survival value that it had previously lacked. Many other changes have followed.

Some Cornerstone Sweet Corn Varieties

1832	"Sweet" or "Sugar"	1897	Mammoth White Cory
1848	Hematite Sweet	1902	Golden Bantam
1850	Old Colony	1905	Howling Mob
1850	Stowell's Evergreen	1919	Whipple's Early White
1855	Burr's Improved	1921	Whipple's Early Yellow
1863	Black Mexican	1925	Golden Early Market
1885	Cory	1925	Sunshine
1889	Shoe Peg	1933	Golden Cross Bantam. Hybrids now predominate
1890	Country Gentleman		

All-America sweet corn winners are: 1934, Kingscrost Bantam (Northrup, King), Stowell Evergreen Hybrid (Associated); 1935, Hybrid Bantam (Sioux City Seed Co.); 1936, Golden Colonel (Associated); 1939, Ear Pack Bantam 12-Rowed (Northrup, King), Aristogold Bantam (Michael-Leonard); 1940, Ioana (Iowa State; Associated); 1941, Allegheny Hybrid (Associated), Spancross (Conn.); 1942, Topflight Bantam (Michael-Leonard), Lincoln (Conn.); 1945, Goldengrain (Michael-Leonard); 1947, Erie (Associated); 1949, Flagship (Corneli); 1950, Iochief (Iowa State).

White varieties predominated for 70 years after sweet corn became valuable in the garden. At the start of the present century a few yellow varieties were known, such as Gold Nugget and Gold Coin, but most consumers placed the yellow kinds in a

category with horse or chicken corn. Then, in 1902, W. Atlee Burpee introduced Golden Bantam, and the preference for yellow varieties began.

Connecticut Station hybrids have been named by two systems.[352] The first system used an abbreviation of the varietal name (from which at least one inbred was derived) plus the suffix "cross" to distinguish hybrids from varieties. Thus, Spancross indicated one inbred of this hybrid was derived from Spanish Gold. Marcross, C6.13, had one inbred (C13) out of Golden Early Market. At first the Connecticut Station had two Marcross corns, Marcross C6.13 and Marcross P39.C13. But the trade refused to accept the numbers in addition to the names so Marcross P39.C13 was named Carmelcross from the location of the experimental farm at Mt. Carmel. In 1941 a new naming system was begun. It uses names from American history, the earlier the name in American history the earlier the hybrid, e.g., Lexington, Lincoln, Lee.

Associated Seed Growers use Indian names for their hybrids, e.g., Erie, Sachem. Michael Leonard Co. uses a combination of two words for describing their hybrids, e.g., Tendermost, Goldengrain. Robson Seed Farms use the word Seneca in most of their hybrids.

The word "corn" has a special meaning in North America. In Europe, it applies to oats, wheat, barley, or rye, as well as to Indian corn. The references to corn in the Bible probably mean only the small grains, since Indian corn or maize was not known in the Eastern Hemisphere prior to the discovery of America.

Varieties

Because of cross-pollination, corn is maintained in an extremely heterozygous condition (except in inbreds as discussed later). Most corn varieties are so considerably mixed that they are changed readily by selection under a new environment, and there are many strains within most important varieties. In fact, there may be greater differences among strains within a variety than among varieties of the same season. Thus, in choosing the strain of corn to plant, it is important to know that it has performed well in the given locality or under similar soil and seasonal conditions.

Open-Pollinated Varieties

A. Ears black at maturity.
 1. Early: Pickaninny.
 2. Later: Black Mexican.

B. Ears white at maturity.
 1. Early: Midget, Luther Hill, Early Market, Early Pearl.
 2. Later: Country Gentleman, Howling Mob, Stowell's Evergreen, Honey June.

C. Ears yellow at maturity.
 1. Ears small (about 4–5 inches long; 8-rowed); earliest group: Banting, Golden Gem, Golden Midget.
 2. Ears medium or intermediate size (5–6 inches long; 8-rowed): Goldban, Dorinny, Golden Bantam, Bardens Wonder Bantam, Charlevoix.
 3. Ears large (8–9 inches long; 10–16 rowed): Burbank Golden Bantam, Bantam Evergreen, Golden Early Market, Golden Early Sweet, Golden Wedding, Whipple's Early Yellow, Golden Giant, Improved Golden Bantam.

Golden Bantam has long been the standard of excellence in open-pollinated yellow sweet corn. The true strain of Golden Bantam is 8-rowed, but modified strains may be 10-, 12- or even 14-rowed. In short-season areas, growers plant such early yellow varieties as Banting, Golden Early Market, and Golden Early Sweet. Some late varieties are Stowell's Evergreen, Country Gentleman, and Howling Mob. Hybrids have assumed chief importance.

Hybrids

Definition. The production of hybrids has been discussed under Seed Production. The term hybrid in sweet corn refers to first-generation progeny of inbred lines crossed with one or more inbreds or a variety, as explained later under Single Cross, Double Cross, Three-Way Cross, and Top Cross. Without pure lines there is only limited control over the heredity, whereas with pure lines control is at a maximum.

Most sweet corn hybrids have originated since 1933, when G. M. Smith of the U. S. Department of Agriculture, working at Purdue University, introduced Golden Cross Bantam. But in 1930, F. H. Woodruff & Sons commenced a breeding program at Milford, Conn., and other firms have been encouraged by the outstanding inbreds developed by Dr. D. F. Jones and Dr. W. R. Singleton at the Connecticut Experiment Station. The success

with sweet corn has prompted breeders to do similar work with other vegetables.

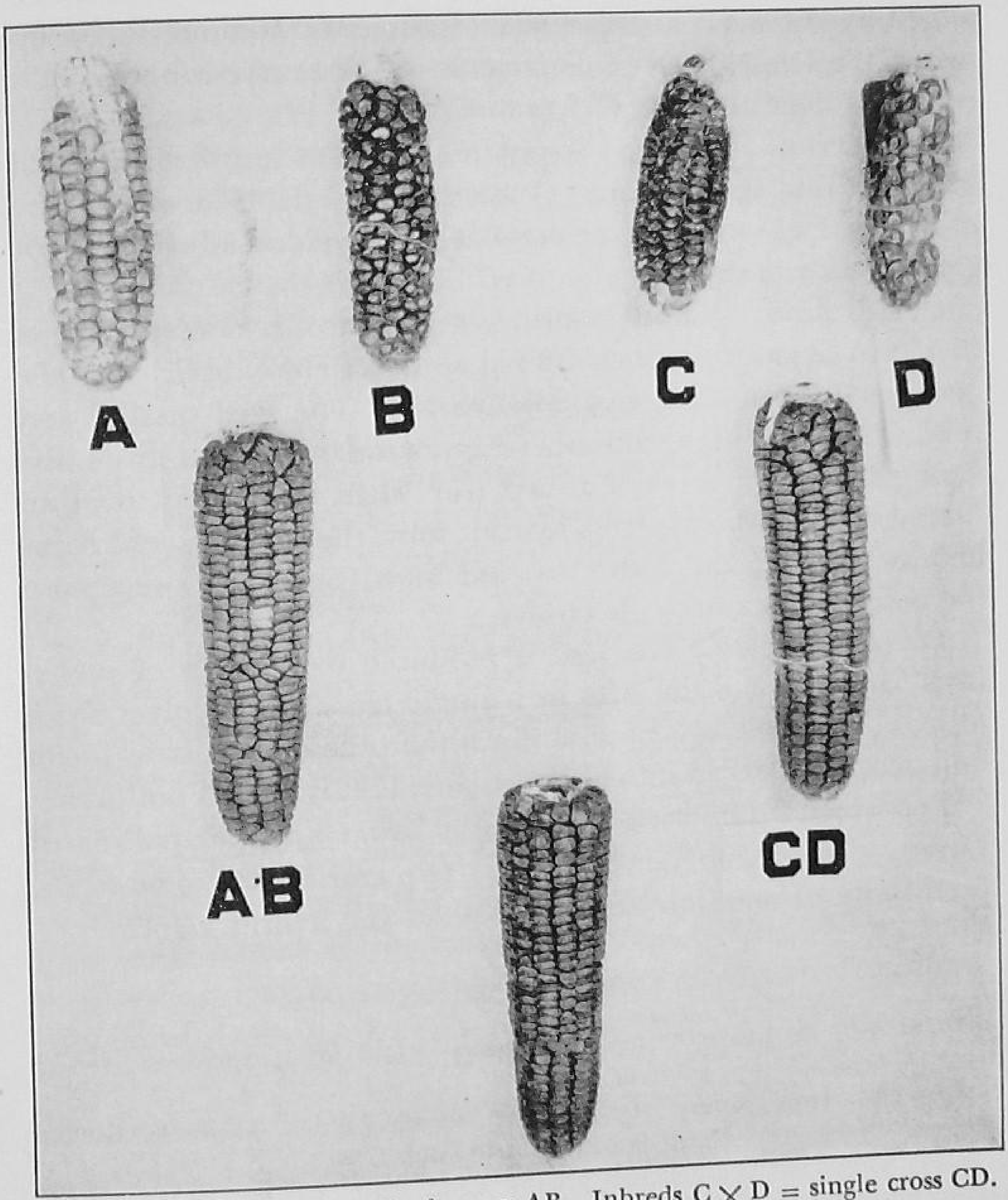

FIG. 14. Inbreds A × B = Single cross AB. Inbreds C × D = single cross CD. Single crosses AB × CD = double cross ABCD. Most good hybrid sweet corn strains used commercially are single crosses. Nearly all field corn hybrids used commercially are double crosses. (*Courtesy Dr. E. S. Haber, Iowa State College.*)

Inbred. An inbred strain is uniform in gross characteristics owing to self- or sib-pollination (brother and sister) for several generations. Usually it is deficient in vigor. Examples are:

Purdue 39 or more simply P39 (Golden Bantam inbred line), Connecticut 13 or C13 (Golden Early Market line). "C13 is used in practically all of the early sweet corn hybrids produced either by the various experiment stations or commercial seedsmen. We know of no productive, early, disease-resistant market corn that does not have C13 as one parent." [352]

Single cross. The seed is produced by the transfer of pollen from one inbred to the silks of another inbred. The uniformity of plants, ears, and time of maturity are decided advantages for commercial canning.

Double cross. A double cross is a hybrid of two single crosses that involves four different inbred strains. Here, both the male and female plants are vigorous hybrids. The seed quality and production are high, and there is abundant pollen from the male parent, which is not always true when this parent is of an inbred strain. Double-cross hybrids form the basis of field corns because yield is the factor stressed most, but with sweet corn the best hybrids are single crosses.

Three-way cross. The seed is produced by transfer of pollen from an inbred to the silks of a single cross. It involves three inbreds. It is slightly more uniform than the double cross but is impractical unless an inbred is available that is a good pollinator.

Top cross. The seed is produced from an open-pollinated variety × an inbred, or vice versa. Top crosses lack some of the uniformity of other crosses and some of the hybrid vigor.

Hybrid Sweet Corn Maturity Groups

Extra early (Spancross group): Pocahontas, Gold Mine, Spancross, Seneca 60 × 13, Seneca Dawn, Priscilla.

Early (Marcross group): Sugar Prince, Seneca Golden, Marcross, Golden Rocket, Washington, North Star, New Earligold.

Early midseason (Carmelcross group): Gold Rush, Golden Rule, Carmelcross, Katahdin Gold, Iogold No. 51, Walden, Jackson, Topcross Maine Bantam, Wisconsin Golden, Kingscrost Improved, Kingscrost Bantam.

Midseason (Hoosier Gold group): Sencross Improved, Wisconsin 804, 810, and 811, Vinegold, Kennebec, F-M Cross, Tendergold, Madison, Penndale, Seneca Chief, Golden Security.

Late midseason (Golden Cross Bantam group): Erie, Early Tendermost, Victory Golden, Cream-O-Gold, Golden Cross Bantam, Golden Crown, Calumet, Ioana.

Late (Wilson group): Tender Blonde, Aristogold, Bantam No. 2, Magnagold, Seneca Giant, Wilson, Golden Hybrid 2439, Golden Supreme.

Very late (Mammoth group): Rosebud, Big Mo, Flagship, Golden State, Iochief, White Golden Cross, Country Gentleman Illinois 8 × 6, Stowell's Evergreen Hybrid.

ADVANTAGES. Hybrids show a marked increase over varieties in height of stalk, yield, uniformity of size and maturity, quality, and pest resistance. Probably 95 percent of the sweet corn produced commercially consists of hybrids.

DISADVANTAGES. Hybrid corn is valuable chiefly in the first generation. The crossing must be repeated each year to provide an available supply of hybrid seed. Seed saved from the hybrids may be inferior to ordinary varieties.

The Inflorescence

TASSEL. The tassel, which is the source of pollen, consists of a broad panicle comprising the central rachis, or spike, and its lateral branches, in a spiral arrangement. It terminates the main stem and sometimes the stems of suckers.

EAR. The ear is a thickened spike. It originates in the axil of one of the lower leaves and is borne on a short branch or shank. The spikelets occur in pairs and each contains two florets or at least one complete floret (the upper one) and the rudiment of a second. Because the lower flower is usually abortive, only one grain, instead of two, is produced. The grains on the ear are typically double-rowed, but in certain cases, e.g., Country Gentleman, both flowers of the spikelet develop grains, which results in crowding and an irregular arrangement. Leaves arise from each node of the shank and form the husks.

Producing Sweet Corn

CLIMATE, WEATHER, AND SOIL

The length of the frost-free season, though significant, does not necessarily determine whether sweet corn will succeed. The higher the temperature, the more rapid the rate of development. For example, the number of days from planting to silking of Golden Bantam may vary from 65 to 79 and of Golden Cross Bantam from 80 to 110. Corn is a heat-loving plant while growing. But once the usable stage is reached cool temperatures retard the change of sugar into starch in the kernels, whereas

high temperatures hasten it; for this reason ears that ripen in cool weather are of best quality. The main regions of production are in northern areas.

Sweet corn succeeds on any soil that is suitable for general crops. A warm soil with some sand in it is usually desirable in northern areas and for early market. If a large yield is more important than early maturity, a rich soil retentive of moisture is best, for sweet corn draws heavily on soil moisture. Silts, silt loams, and clay loams generally produce higher yields than do sandy loams. Rich river-bottom lands are often used because these soils are not only high in mineral nutrients but are less likely to be deficient in moisture at any time. The yield is usually poor on very acid soils.

Manure and Fertilizer

Nitrogen, phosphorus, and potassium enter the plant and move independently from tissue to tissue. Nitrogen accumulation in the plant reaches a maximum at silking time and ceases about 4 weeks later. Nitrogen continues to move into the grain from other tissues until maturity. Phosphorus accumulation does not cease until about maturity. Phosphorus also moves into the grain from other tissues. Potassium accumulation reaches a maximum about 3 weeks after silking, then there is an actual loss, largely from the leaves and stems. No marked accumulation of potassium occurs in the grain.[335]

Placement. Germination and root growth may be retarded when fertilizer is applied with the seed. Desirable effects of fertilizer on early growth, maturity, and yield are related to root development. With relatively small amounts, application in bands 2 inches from the sides of the row and an inch deeper than the seed is superior to use in the row or to broadcasting. With large amounts, it may be wise to apply part of the fertilizer broadcast and part in bands. Plow-sole applications are often best, especially on the heavier soils; the fertilizer is placed, through an attachment above the plow, in bands on the plow sole, i.e., at the bottom of the plow furrow, at the time the soil is turned. Even in dry weather the soil at this depth is likely to be damp enough to make the nutrients available to the roots.

Benefits may be obtained by applying phosphorus and potash while fitting the soil for planting, and then nitrogen as a side-dressing [393] at the last cultivation.

Rate. One plan is to use both manure and fertilizer, e.g., 5–10 tons of manure plus 100–300 pounds of a mixed fertilizer. Where no manure is used 300–600 pounds of a mixed fertilizer is often suitable. But the best rate and material to use depends on many factors, e.g., type of soil, natural fertility, and previous crops.

Seeding

Seeding may be done in drill rows or in hills. Seeding in rows 2½–3½ feet apart and thinning to 9–12 inches when the plants are about 6 inches high, or in hills 2½–3½ feet apart, according to variety, are good practices. The earlier, smaller-growing varieties are spaced somewhat closer than the later, larger ones. Sweet corn sown for commercial processing is seldom thinned. Mechanical pickers cannot be centered on rows narrower than 38 inches apart.

Early in the spring with relatively cool weather and fairly high soil moisture, the seed should be sown shallow, roughly ½–1 inch deep. Too deeply sown seed may rot before germination (see Seed Treatment). Later in the season when the soil is much warmer and generally drier, sowing should be done 1½–3 inches deep. Seed is covered somewhat more deeply in sandy than in heavier soil.

In New York [121] six spacing practices were studied in relation to production, rate of maturity, length of ear, percentage of 2-eared plants, plant height, and the degree of tillering. An early type (Seneca Golden), a second-early type (Tendergold), and a main-season type (Golden Cross) were used. The 4-year mean yield for Seneca Golden was highest (5.05 tons per acre) when sown in 30-inch rows with plants 9 inches apart. Tendergold produced the highest 3-year mean yield (5.18 tons per acre) when sown in 30- or 36-inch rows with plants 12 inches apart. The highest mean yield for 3 years of Golden Cross was 5.56 tons per acre when sown in 36-inch drill rows with plants 12 inches apart. The rate of maturity was most rapid in 36-inch drill rows with the plants 12 inches apart and in 36-inch check rows. No real differences in height due to spacing occurred within any type. The most tillers on Seneca Golden and Tendergold were produced when sown in 36-inch drill rows with plants 12 inches apart, and on Golden Cross in 36-inch check and drill rows. The highest percentage of 2-eared plants for all three

types was produced in 36-inch check rows. The ears of Seneca Golden were shorter from the 30-inch drill rows with plants 9 inches apart than from the 36-inch rows. Tendergold and Golden Cross ears averaged more than an inch longer when grown in 36-inch check rows than in 30-inch rows with plants 9 inches apart.

These suggestions have been made in Illinois.[189] *Early dwarf types* (less than 5½ feet tall); bushy; numerous suckers; resemble early flint corn): In drill rows, space the plants about 8 inches apart; in check rows leave 3–4 plants per hill. Sowing any but the very earliest hybrids in less than 36-inch rows is not justified. *Midseason types* (5½–7 feet tall; somewhat bushy; fewer suckers than the early dwarf types; flint corn characteristics dominate): Check plant 36 × 36 or 38 × 38 inches; in northern Illinois 4 plants per hill, and in central Illinois 3 plants. *Late types* (6–8 feet tall; suckers medium to few; resemble dent corn): Check plant 38 × 38 or 40 × 40 inches; in northern Illinois 4 plants per hill, and in central Illinois 3 plants.

In Washington (Washington Experiment Station *Annual Report,* 1946), sweet corn sown with the single stalks 6 inches apart, in rows 3 feet apart, gave higher yields (without irrigation) than in hills with several stalks but with the same unit area per stalk. With a greater area per stalk, yields were almost in proportion to the decrease in the number of plants. The greater the concentration of stalks per hill, the more nubbins and sterile plants.

Kernels of different grades usually come from different portions of the ear, i.e., the small and medium round kernels from the tip, the large round and thick flats from the butt, and the various flat grades from the center. Hence the old "tip" and "butt" practice with open-pollinated seed ears. The remaining kernels were flats, and though they were not too well graded they did sow well with the old type hill-drop planters. But with the advent of hybrids, this has changed even to the use of new plates and planters. Each kernel from a hybrid seed ear carries the same germ plasm. Plants grown from round seed produce the same kind of ears as those from flat seed of the same hybrid.

For canning, it is wise to grade the seed as large or small and to sow these in separate blocks in the field. The uniformity in time of maturity within each block is an advantage over uneven maturation with seed of mixed sizes. The larger kernels give a better stand and stronger plants which reach the canning stage 2–3 days earlier than those from small seed. The same planter plates should be used for both sizes of seed even though more small kernels will be sown. The probably poorer stand from the small kernels makes it advisable to sow a larger number. The weight of seed sown per acre is about the same.

Pollination. Corn may not fill well unless sown in blocks, and so a long single row should be avoided. Corn is unlike most vegetables in that there is a direct, conspicuous effect from pollination on the resulting crop, i.e., xenia, as explained earlier. This is shown where two types, as yellow and white, or sweet and field corn, are grown side by side. Pollen of white corn will cause some of the kernels of yellow kinds to be white, giving the ears a spotted appearance; yellow corn will cause white corn to be spotted with yellow kernels. Sweet corn should not be grown near field or pop corn.

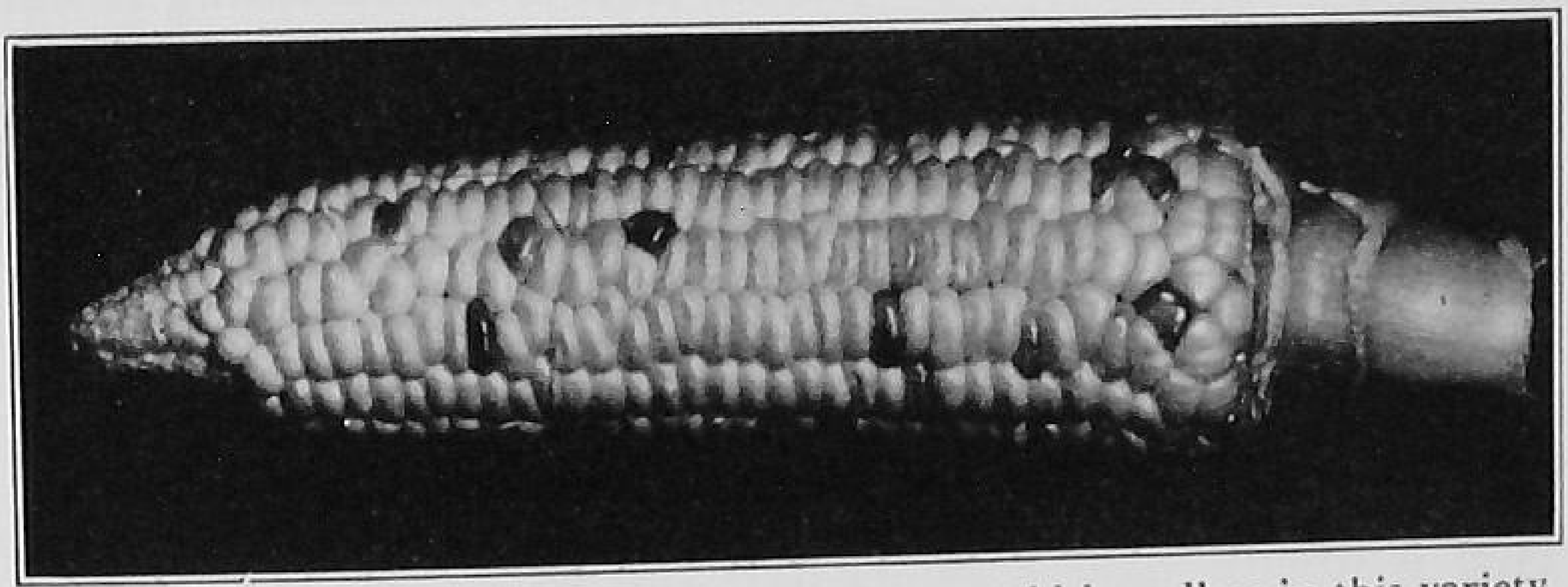

Fig. 15. Some of the kernels, which normally would be yellow in this variety, are black owing to the direct influence of the pollen of a black variety planted close to it. This effect is known as xenia.

Time of seeding. Corn should not be sown too early as the seed may rot in cold soil. If the cold weather checks the seedlings, later sowings may do better than early ones. It is usually safe to sow sweet corn about the average date of the last killing frost. For a succession of ears, it is usual to sow on the same date different kinds with different dates of maturity. In certain areas, seeding is timed so as to reduce corn borer infestation.

Heat units are useful in regulating cannery schedules (see Peas). But the base temperature is 50°F. instead of the 40°F. as in peas.

Interplanting. A common practice in the East is to sow 1 row of pumpkin to 3 rows of corn in the same field.

Sucker Removal

Removing the suckers has been thought to increase the yield by allowing nutrients brought into the plant from the soil to go to the ears. But the raw materials (water, carbon dioxide, and

mineral nutrients) brought into the plant from the soil are not utilized in the development of the ear, or in other growth, until they have been built up into complex compounds (e.g., sugars and proteins) in the green parts of the plant. The suckers themselves aid in this process, and removing them results in a decrease in the manufacturing area. Tests made at many places on removing suckers at different times and in different ways have shown no real benefits in earliness, size of ear, or total yield. In fact, the practice, particularly late suckering, has often been harmful. Since removal of suckers increases the labor and cost of production and reduces the yield when suckering is delayed, since the removal of suckers over a foot long tends to disturb the main plant, and since there is no gain in earliness, size, or yield, the practice usually results in more loss than gain.

Irrigation

Surface irrigation is practiced in irrigation districts. The land is made as smooth as possible so that the water may run steadily from the higher to the lower end of the field. The land is usually plowed in the fall and harrowed down immediately, and, the following spring, a land leveler or float is drawn diagonally across it.

Arrangement of rows. It is not always practicable to plant straight rows on irrigated land as the successful use of the water depends much on its flow following the slope of the land. A field may slope in one direction part way and then change to another direction for the remainder of its length, or it may slope at an angle to the road allowance and other base lines. If the rule is followed "as the slope so the row," the field may be in a zigzag pattern after the plants begin to grow. This method aids good distribution of water to all the plants and hence uniform growth and maturity.

Soil type. Some soils need irrigation for 2 hours before the water soaks to the root system; on certain other soils irrigation for ½ hour is sufficient. Sandy soils allow water to pass through freely, and so water must be applied frequently, perhaps every 8–10 days, especially in midsummer when the plants are growing vigorously. Heavy soil takes up water comparatively slowly and gives it up slowly; therefore, less irrigation water is used on heavy soil. The cooling effect of water on heavy soils may also influ-

ence the rate of growth. Accordingly, on heavy clay land water is applied every 10–16 days rather than at shorter intervals.

Cultivation and Weed Control

Stirring the soil with a weeder, a spike-tooth harrow, or a rotary hoe before the corn comes up is a good practice as it destroys the weeds and gives the corn a chance to get started ahead of them. Deep cultivation close to the plants may damage the roots. Destruction of weeds is the main objective of shallow cultivation and is much more significant than conservation of moisture by a dust mulch. No striking differences appear [411] during the growing season between corn on cultivated soil and on shaved soil. (See also Chapter 15, Weed Killers.)

Harvesting

Milk stage and its determination. High quality in any sweet corn prevails only for a short time, and so close attention must be given to harvesting the ears. Early types pass through the best edible stages more rapidly than later ones. For finest quality, the ears are harvested in the milk stage, while they are juicy, yet plump and firm, and the silk is fairly dry. The tip should be filled out so that the husk is tight and the tip is blunt. In the nail test for suitable maturity, the thumbnail is thrust into the kernel; if the exudate is milky, the corn is in the milk stage; if dough is forced out, the corn is too ripe for best quality. Experienced growers can usually tell quickly by grasping the ear whether it is ready for pulling. The inexperienced spread the husk slightly and examine the kernels.

Frequency of picking. For fresh corn-on-the-cob, frequent picking is wise as all ears do not mature at the same time. For canning, the usual practice is to harvest a field only once; hence uniformity in maturity is an advantage. But in years of short crops a second harvesting may be done. The quality and grade of a pack are lowered if early, midseason, and late plants are grown as a mixed crop. Hybrids are more uniform in ripening than varieties.

In New York [314] there are two methods of buying sweet corn for processing. The old method is to pay a stipulated price per 100 pounds of corn in the husk just as it is delivered. The U. S. Department of Agriculture crop reports are given in terms of

this gross weight. But nearly all processors in the State now pay for the corn on "the average basis." This means that a sample consisting of either 25 or 50 pounds is taken from each load. The husks and all undeveloped, damaged, or worthless ears are removed. Then the good ears are weighed, and this weight is computed as a percentage of the original sample. Good crops of uniform maturity, reasonably well picked, commonly give an "average" of from 68 to 73 percent. Sweet corn for whole-kernel or quick-freeze pack is harvested a day or two younger than that for cream-style canned corn, and does not yield quite so much or "average" so high.

Sugar to starch. Nearly 60 percent of the sugar changes to starch within 36 hours after pulling and even more rapidly under warm conditions. If corn is pulled during the heat of the day and placed in piles or in sacks to be taken to market next morning it heats and loses its sweetness before reaching the consumer. It is better to pull corn early in the morning when the ears are cool and take it directly to market. For canning, the ears should be harvested in the morning, hauled directly to the factory, and processed the same day. High temperatures due to weather or to ears being left in piles or in trucks or wagons for several hours cause a loss of flavor and quality, even though sugar is added when the corn is canned.

The succulometer is an instrument for measuring the maturity of whole-kernel corn, based on the quantity of extractable juice.[214] The older the corn gets, the smaller the quantity of juice that is extracted.

Yield. A good yield per acre is 8,000–10,000 ears or 3–4 tons with husks removed. About 600–800 pounds of canned corn from a ton of sweet corn is a fair estimate.

Methods. The "sack" method of harvesting may be used for market corn or when the processing plant lacks the facilities to handle bulk corn. The corn is picked directly into grain-type sacks; these are then hauled from the field to the truck on a sled, wagon, or trailer. In the "trailer" method the corn is picked into a trailer pulled by a tractor; the corn is then dumped into a truck from an elevated ramp or platform. In the "truck" method the corn is picked directly into the truck that hauls the corn to the processor. This method, as well as the trailer method, is used only when the processor is equipped to handle bulk corn.

Another method for a large acreage of market corn is to have picking crews make small piles of ears every 15–20 feet at the center of each four rows. This leaves the corn in small piles in the shade where it will not heat until gathered by truck.

In picking sweet corn by hand the ears are easily broken off with but a short portion of the stalk by firmly grasping the shank just below the butt of the ear with one hand while the other hand bends the ear downward until it breaks loose. With a little experience the ears of most varieties can be broken off reasonably short with one hand. If the shank at the base of the ear is more than 2 inches long, the excess length should be removed before packing the corn for market.[814]

Mechanical harvesters are useful in large acreages of canning corn. The average "jerker's" rate is about ⅜ of a ton per hour per man. In 3 tons per acre corn, one harvester is equivalent to a crew of 8–10 men. In heavier corn the ratio is even higher.

Storage

To retain sugar and to preserve flavor, corn in the husks as it comes from the field should be cooled to 31–32°F.; submerging it in ice water for at least ½ hour removes field heat and heat produced by respiration. Loss of sugar is about 4 times as rapid at 50°F. as at 32°F. Even at 32°F. over 20 percent of the initial sugar disappears through respiration and conversion to starch in 4 days. Corn can be kept salable at 31–32°F. and 90–95 percent relative humidity for 1–4 weeks, depending on its condition when stored.

In Indiana [141] some of the sweet corn was husked and silked ready for cooking before being *packaged*. Some had only an inch strip of the husk removed and no attempt was made to silk it. The latter outsold the completely husked corn 2 to 1.

Insect and Disease Control

Corn earworm eggs are laid on the silks. The mature, 1½-inch long, greasy caterpillars feed first on the silk and later work down into the ear, eating the kernels. The second generation usually does the most damage. Early sweet corn usually escapes severe damage. One control is to dust with DDT: (*a*) after the ears have formed but before the silks appear; (*b*) when about

25 percent of the silk has appeared; and (*c*) about 3 days later. The dust is applied so as to thoroughly coat the silk on which the eggs are laid.

European corn borer caterpillars are ¾–⅞ inch long, with a brown head and a cream body with light-brown markings. The worms burrow through stalk, ears, and stubble after midsummer. Infested plants often have broken or detached tassels and holes with protruding "borings" in the sides of the stalks. Infested stalks may collapse. The eggs are deposited in clusters of about 20 on the undersurface of leaves, usually along the midrib. DDT, ryania, or rotenone, applied 4 times at 5-day intervals, starting soon after the eggs hatch, or when the stalks are about 1½ feet high, should be directed downward into the crown of the plant, because the young larvae crawl to the base of the leaves and feed in the whorl or crown of the plant. For the later applications, after the ear shoots have started to show, it is well to direct one dust or spray toward ear level. All refuse should be destroyed by feeding (unless treated with DDT) or by plowing under in early spring.

Bacterial wilt (*Stewart's disease*) causes young plants to wilt or die, to develop long pale-green streaks in the leaves, remain stunted, tassel prematurely, and produce no ears or only nubbins. A slice through the stalk shows yellow slime oozing from the vessels. Flea beetles feed on such plants in summer or fall, live over winter, and carry the wilt bacteria to the young plants in spring as they feed on them. Later they, and new broods, spread the infection still further. The large-growing hybrids are the more resistant.

Smut galls, which form in the tassel, stem, leaf, or ear, are at first white, then black, finally bursting and exposing dusty spore masses. The organism lives in the soil. Controls are burning the young bolls, rotating crops, avoiding smut-infested manure, and insecticides directed against the corn borer.

Root rot infection may occur from diseased seed or infested soil. Yield is reduced, growth and maturity are irregular, stalks are barren or bear nubbin ears, and plants die prematurely. Seed treatment with an organic mercury dust, rotation, and high fertility help avoid damage.

Ear rots caused by several fungi produce imperfectly formed, soft, and often moldy ears, particularly in moist, warm weather.

Controls are rotation, sanitation, clean seed, and resistant strains.

POP CORN

Sweet corn is harvested at an immature (milk) stage for table use, but pop corn ears or kernels must ripen on the plant. Therefore, the need for a longer growing season, other things being equal, is indicated for pop corn. But pop corn is safely sown somewhat earlier than sweet corn, perhaps a week earlier, as the hard, vitreous seed is not so easily damaged if the weather turns cold and wet. Most pop corn is grown in the corn belt of the United States. Production is about 250 million pounds a year.

History

The growing and popping of pop corn is almost entirely restricted to this continent. Pop corn was grown and popped by the southern tribes of Indians before the coming of Columbus. Pop corn kernels and specially shaped earthenware dishes thought to be corn poppers have been found among prehistoric Indian remains in South America.

The first pop corn hybrid to be distributed (1935) was Minnhybrid 250; it is white. The first seed of yellow pop corn hybrids distributed commercially was grown at Purdue University in 1940. Since then pop corn hybrids have largely replaced varieties, owing to the increase in yields, standing ability, and popping expansion, which appeal to both the producer and the customer.

Why Pop Corn Pops

Pop corn pops because the horny endosperm or colloidal matrix in which the starch grains are embedded confines the steam (moisture in the kernel) generated by heat until it develops enough force to suddenly explode the kernel. The softer types of corn permit the gradual escape of the steam so that there is not enough pressure to cause the sudden explosion necessary for complete popping.

Popping Properties of Starchy Corns

Starchy corns are classified as pop, flint, dent, and flour, on the basis of the distribution and relative proportions of horny

and soft starch in the endosperm. The endosperm of the best pop corn strains is corneous or hard throughout or contains only a small central core of soft starch. In flint corn the endosperm consists of a little soft starch, near the embryo, completely surrounded by corneous starch. In dent corn the corneous starch is confined mainly to the sides of the kernels, soft starch constituting a larger proportion than in flint corn. In flour corn the endosperm is nearly all soft starch. The popping properties of the different corns follow rather closely the relative proportions of hard or corneous starch in the endosperm. Pop corn, with the most hard starch, pops much better than the others. Flint corn may pop poorly or fairly well, depending on the strain, and, in fact, pop corns are often small-kerneled flint types. Dent corn rarely will pop, though a few kernels may do so feebly. Flour corn will not pop at all.

Color in Pop Corn

The kernels of most pop corns are yellow or white, but there are red and purple varieties. Red color is carried either in the pericarp or in the aleurone (outer coat of the endosperm just beneath the hull); purple color (blue or black) is carried only in the aleurone. Red and blue pop corns are white when popped, but the dark hulls make the popped corn unattractive.

Varieties

A. Pearl. Broad, rounded, smooth kernels, and heavy chaff (flower glumes) on the tips.

1. White kernels: White Pearl, Spanish (Eight-Row).
2. Yellow kernels: Yellow Pearl (Golden Pearl), Supergold (Sunburst), Tom Thumb, Queen Golden, South American (Dynamite, Mushroom, Giant Yellow, T.N.T.), Superb.
3. Blue-black kernels: Black Beauty, Blue Snow.
4. Red or pinkish ears or kernels: Pinkie, Ornamental Strawberry.
5. Variegated kernels: Popinjay (Rainbow), Carnival.

B. Jap or hull-less. Shoepeg kernels (long and narrow, with either a pointed or a rounded crown), and very light chaff; ears short and thick; kernels not in distinct rows.

1. White kernels: Japanese Hulless (Australian Hulless, Dwarf Rice, White Hulless).
2. Yellow kernels: Golden Hulless (Baby Rice).

C. Rice. Sharply pointed kernels, often ending in a hook or beak, and rather heavy chaff.
1. White kernels: White Rice (Snowball).
2. Yellow kernels: New Hampshire Golden.
3. Red kernels: Red Rice.

Hybrids

A. White.
Minnhybrid 250, Illinois Hybrid Hulless.

B. Yellow.
1. Large kernels: Purdue 3 (Sg 32 × SA 24), Purdue 38 ((Sg 32 × Sg 16) × SA 24).
2. Medium large kernels: Purdue 1 (Sg 16 × SA 24), Purdue 31 ((Sg 16 × Sg 18) × SA 24), Purdue 32 ((Sg 30A × Sg 18) × SA 24).
3. Medium small kernels: Purdue 34 ((Sg 32 × Sg 16) × Sg 18), Purdue 20 (Sg 30A × Sg 18), Purdue 22 (Sg 16 × Sg 18).

The Yellow Pearl group includes the chief commercial varieties, e.g., South American, but hybrids have largely replaced varieties for reasons mentioned earlier. The inbreds that have been used to produce the outstanding Purdue hybrids have been developed either from South American (SA) or from an earlier form of it (Sg).

PRODUCING POP CORN

Seeding

In regions like Iowa, seeding, particularly of early pop corn, may be delayed somewhat longer than for field corn, thus giving more time for weed seeds to sprout and be killed. On clean land, pop corn may be sown a week ahead of dent corn. The larger-seeded pop corns require about 4–7 pounds per acre when 4–5 seeds are sown per hill. Slightly closer sowing of pop corn than of dent corn is advisable because of the smaller plants. The rows may be as close as 36 inches except where two-row pickers, which will not handle rows closer than 40 inches, are used.

One plan [50] is to blank-list in the fall, throw in the ridges about 2 weeks before seeding, and at seeding time nose out the old furrows with a loose-ground lister or with a furrow-opener attachment on the corn planter. This procedure kills two crops of early weeds cheaply and provides a warmer and finer seedbed than ground freshly listed.

Location

Pop corn should not be grown near other corn because the two types will cross-pollinate. Though this does not affect the popping quality of the corn, it may affect its taste and color and it does ruin it for seed purposes.

Harvesting

Pop corn must mature completely before frost and dry thoroughly on the stalk before harvest. Most mechanical huskers can be adjusted to pick pop corn well. The rolls are set close together, and, if the corn is to be snapped, the husking rolls are covered or removed. Some picker manufacturers put out special attachments for harvesting pop corn. In some eastern states pop corn is cut and shocked, and the ears are allowed to cure in the shock. They are later husked out by hand or put through a corn shredder.

Curing and Storing

Pop corn should not be harvested until the moisture drops to 20 percent and preferably to 15–17 percent. Complete normal maturity of the crop before the first killing frost promotes best quality and allows the grain to dry on the stalk to good cribbing condition. In the southern Great Plains and often in the southern edge of the corn belt, pop corn will dry in the field to a good content for popping. But in the central and northern parts of the corn belt it seldom reaches this condition at husking time.

Cribs 3–4 feet wide provide adequate ventilation to cure the corn to optimum moisture. If cribs are wider, partitions or airways should be built down the middle. Precaution should be taken to prevent damage by mice and sparrows. Under the Pure Foods Act pop corn contaminated with rodent excreta may be condemned.

Artificial drying enables growers to move the corn quickly into market channels. It is best to operate driers so that ear corn will not lose more than 1 percent moisture per day; or, if artificial heat is used, to stay under 90°F.

Effect of Moisture on Popping

Pop corn pops at its best when a standard electric popper, a moderate quantity of seasoning, and about 13½ percent mois-

ture, as determined by the Tag-Heppenstall moisture meter, are used.[50] Slightly higher moisture is suitable when a wire popper is used.

Kernels that are too dry pop feebly with a "muffled" sound; they often only partly split open, and the unpopped area is dark and scorched. Too moist corn pops with a loud explosion, but the kernels are small, rough, jagged, and tough.

Popping expansion is the volume ratio of the popped to the unpopped corn; e.g., if 100 cubic centimeters of unpopped corn gives 2,400 cubic centimeters of popped corn, the sample has a popping expansion of 24. For bulk retail samples, expansions of under 20 are considered poor, those of 20–25 fair, those of 25–30 good, and those of 30 or more excellent. The popped product is usually sold by volume rather than by weight.

In the home, pop corn will quickly become too dry unless kept hermetically sealed. Corn kept sealed in a fruit jar retains its popping quality for at least 3 years and perhaps indefinitely in a cool place. To restore moisture properly in corn which has become too dry (and it may become too dry within a week when exposed in a heated room), place it in a normally moist atmosphere for a time and it will take up adequate moisture. The moisture content can also be increased by dampening the kernels slightly and then storing the corn in tight containers for 24–28 hours. Adding water and popping at once is not satisfactory.

Ear corn may be stored 3–4 years at 31–32°F. and 85 percent relative humidity without apparent deterioration in popping quality. A slightly stale or rancid taste may occur in corn 5–6 years old.

Insect and Disease Control

Insect and disease problems, and control measures, for pop corn are similar to those outlined previously for sweet corn.

4 · ROOT CROPS

CARROT

The carrot is an important vegetable because of its large yield per given area, its orange-yellow color which adds attractiveness to foods on a plate, its high vitamin A value, and its keeping quality. In the garden, a good yield is 2–2½ pounds per foot of row, less (about half as much) if the roots are harvested for bunching before fully developed, and more if they are left for late digging. In market gardens, a good yield is 500–700 bushels per acre. Yield for the cannery is about 20 tons per acre.

History

The carrot probably originated in middle Asia (Punjab or Kashmir), with a secondary center of distribution in near Asia. Our carrot is a Mediterranean derivation from Asia Minor types. The wild carrot is an annual, from which the fleshy-rooted, biennial, cultivated form has been developed by selection.

Some of our present varieties represent selections that were made by Vilmorin, a French plant breeder and seedsman of the middle nineteenth century. Early Horn, French Forcing, and Long Orange are very old varieties. Varieties at least 50 years old include Intermediate, Nantes, Danvers, Oxheart, and Chantenay.

Classification and Varieties

A. *Short, stump-rooted.* Useful on heavy soils where pulling is difficult with longer sorts, on shallow soils, and for forcing.
   1. *French Forcing types.* Root round, 2–2½ inches long. Leaf small to medium: French Forcing (Earliest Garden).
   2. *Scarlet Horn types.* Root oval, 3–5 inches long. Leaf small to medium.
      (*a*) Roots blunt ended: Scarlet Horn (Dutch Horn, Short Horn).
      (*b*) Roots pointed: English Horn (Early Horn).

3. *Oxheart types.* Root heart-shaped, 4–5½ inches long, collar deeply sunken. Leaf medium to large: Oxheart (Guerande), Early Gem.

B. *Half-long-rooted.* Length usually less than 8 inches and not more than four times the widest diameter. Includes the leading home, market, and processing varieties.
1. *Nantes types.* Root smooth, cylindrical to tip or with tapering shoulder; thin skin; highest quality.
   (*a*) Root 4–5½ inches long; top small; leaves few: Amsterdam Forcing.
   (*b*) Root 6–7 inches long; top small; leaves few to medium: Nantes (Half Long Nantes, Coreless), Nanchan, Nancy, Nantes Strong Top.
   (*c*) Root 6½–7½ inches long; top medium; leaves medium: Touchon (Sweetheart).
   (*d*) Root 7–8 inches; top heavy: Half Long Red Stump-rooted, Gurney's Coreless, Winter Perfection.
2. *Chantenay types.* Root thick, tapering slowly with abrupt blunt tip; skin thick; good quality.
   (*a*) Root 4½–5½ inches; flesh reddish orange: Chantenay.
   (*b*) Root 4½–5½ inches; flesh reddish orange with core almost same color as flesh; sold by many seedsmen as Chantenay: Red Cored Chantenay (Rubicon).
   (*c*) Root 6–7 inches long: Long Chantenay, Chanticleer.
3. *Danvers types.* Root tapering with semi-blunt tip or long conic; fair quality; flesh often light in color with yellowish core.
   (*a*) Root 6 inches long; color deep orange; leaf small: Supreme Half Long.
   (*b*) Root 6 inches long; early; color often light orange: Half Long Luc (Danvers Luc).
   (*c*) Root 6–7 inches; color light orange to slightly darker: Danvers (Danvers Half Long), Red Cored Danvers.
   (*d*) Root 7½–10 inches; semi-cylindrical rather than long and tapering: Bagley, Goliath, Hutchinson, Leviathan, Longred Coreless (Long Nantes, Danvers Long).

C. *Long-rooted.* The roots may be 10 inches or more long and taper to a long conic tip. Thrive best on a comparatively light soil, though short-topped types are available for heavier soils.
1. *Imperator types.* Root 7–8 inches long. At bunching stage, for which they were bred, the root is long conical with narrow shoulders, and long conic root tip. Later, the shoulders may become square and the root tip thickened and short conic. High quality at bunching stage, but generally slightly coarse as roots approach maturity.
   (*a*) Root 6–7½ inches long; flesh color variable; top medium: Airliner (Short Top Shipper).
   (*b*) Root 7–8 inches; deep orange; top medium to large: Imperator (California Bunching, Lompoc), Morse's Bunching.
   (*c*) Root 7½–8 inches; flesh light to medium orange with light orange core; top medium: Amager, Feonia (Pride of Denmark).
   (*d*) Root 7½–8½ inches; attractive deep orange; top medium: Streamliner, Long Imperator.

2. *James Intermediate types.* Root 7–8 inches long; conic; color and quality only fair, even at bunching stage: James Intermediate (Intermediate Red or Scarlet).
3. *Long Orange types.* Root about 11 inches long, but may be 18 inches long.
   (*a*) Shoulder not especially wide, but wide for a long-rooted type: Long Orange (Long Scarlet), Colossal.
   (*b*) Shoulder narrow: Altringham (Windsor), Long Red.

Chantenay, particularly Red Cored Chantenay, is a leader for general planting, stores well, and is used in canning for whole pack and dicing. The longer *Morse Bunching* (All-America, 1934) and Imperator (All-America, 1933), now the leading bunching varieties from shipping areas, have not monopolized the bunching trade because they are not early enough in many regions. *Nantes,* the so-called "coreless" carrot, ranks first in quality, but its weak, brittle top makes pulling difficult and detracts from its value for bunching; Nantes Strong Top, Nancy, and Nanchan are better for bunching. *Danvers* is a market-garden variety with a stronger plant than Chantenay and with a root that tapers more to the point; it ranks only fair in smoothness, color, and quality. *Supreme Half Long* (All-America, 1937) is longer than Danvers and has a better interior color. *Oxheart, Early Scarlet Horn,* and *French Forcing* are too small and short for bunching, and year-around shipments have largely eliminated culture of carrots under glass.

Plant Characteristics [247]

Root Color

The preferred root color is a uniform deep orange-red. The root changes from a yellowish white, when very young, to whitish yellow, light yellow, dark yellow, orange, or orange-red, owing to the accumulation of carotene in varying intensities of yellow. In fairly uniform strains the larger roots usually have a higher concentration of carotene than smaller roots of the same age. In mixed stocks the larger roots are likely to be lighter colored, especially if the seed was produced near larger, lighter-colored varieties with which the female parent could cross.

Carotene is laid down first in the oldest cells of the phloem and then in the oldest cells of the xylem. Since a carrot root

grows from the cambium, the oldest cells are those immediately adjacent to the epidermis and in the center of the core. As the root grows older, more carotene is deposited in the oldest cells as well as in the cells nearer the cambium, thereby establishing color gradients, which radiate from the center of the root out-

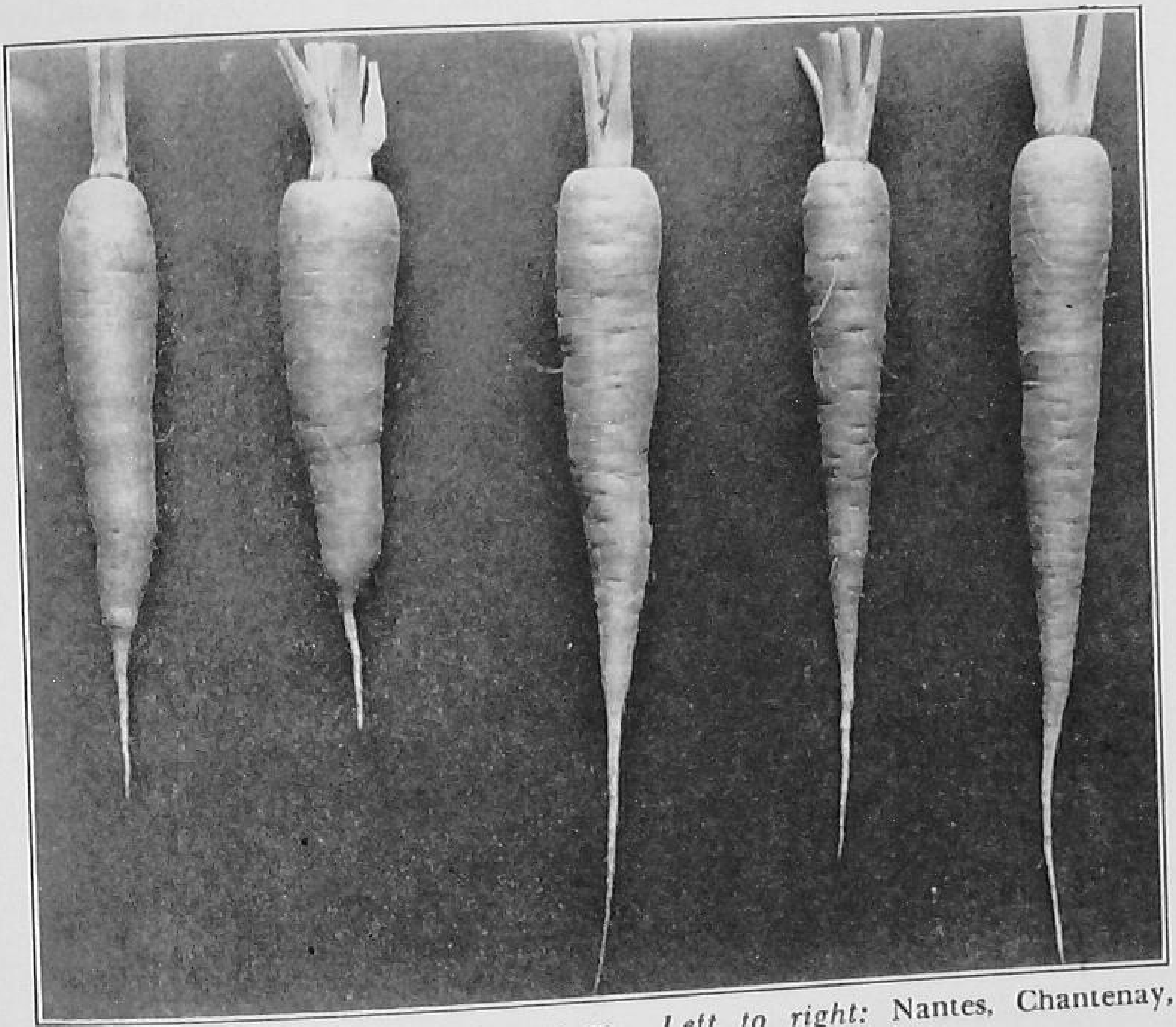

Fig. 16. Carrots at bunching stage. *Left to right:* Nantes, Chantenay, Imperator, Morse Bunching, Streamliner.

ward and from the epidermis inward, leaving a light-colored ring at the cambium. In old or slow-growing carrots this region may become fairly well colored. The vertical development of color is from the top of the root to the tip, for the same reason.

Carotene content is, in general, decreased above 70°F. and below 60°F. Roots grown at 55°F. have less color than those grown at 65°F., and the exterior color is much lighter, because the pigment in the surface layers is reduced. Plants grown at 45°F. after the roots have started to enlarge are still poorer in total color because of more bleached cells at the surface of the root. Cool nights (45°F.) and warm days (65°F.) result in fewer

bleached cells, and hence better color, than continuous growth at 45°F.

Increasing soil moisture from a low to a high percentage decreases the intensity of the color, but in moderately fertile soil an increase in amount of nutrients fails to increase it appreciably. However, a marked deficiency of "plant food" results in smaller size and reduced color. Carrots grown on sandy soils or soils high in humus are usually better colored than those from silt loam soil. Color formation reaches its maximum in fewer days in the earlier than in the later varieties.

Root Shape

Branched or forked roots result from hereditary factors, from the presence of undecayed manure or plant refuse in the soil, from injury to the young taproot, or from any check to its downward growth. Heavy soils produce more misshapen roots than those of lighter or more open texture. Any nutritional factor that affects size or weight also influences shape, since roots, after they are ¾ inch thick, increase in diameter proportionally more rapidly than in length; the diameter increase is first most rapid at the crown and downward. Low soil moisture and low soil phosphorus may result in more pointed roots than where the amounts are optimum. California carrots are longer than those grown from the same lot of seed in Virginia, because of the combined effect of lower soil temperatures and less rainfall or soil moisture.

Typical root shape is most readily produced at 65°F. At 55°F. the roots are longer and more slender; at 75°F. they are shorter and thicker. Growing plants at 45°F. at night and 65°F. during the day results in longer, more slender roots than a uniform 65°F. Growth at 65°F. until root enlargement begins and then at 45°F. results in the upper part being enlarged as usual but the lower part tapering rapidly to a long, thickened taproot. High as well as low temperatures may prevent the normal rounding of the base of half-long and stump-rooted varieties, resulting in tapering bases.

High temperatures and irregular water supply result in deep horizontal depressions in the roots, i.e., a rough surface. Roots grown in Virginia and Louisiana in spring and summer are rougher than those grown in California or Texas in winter or in

the North in fall. Excessive moisture following drought may result in white, corky outgrowths where side roots emerge. Under high temperatures and low rainfall, the shoulders are comparatively square or more sharply rounded. Narrow crowns or sloping shoulders are common in Nantes. When Nantes fails to develop normally, the portion of the root that projects aboveground as a result of washing away of the soil may become necked. This also occurs if partially grown plants are covered with several inches of soil.

Root Size and Weight

Size or weight of root depends on the ability of the leaves to elaborate storage materials in excess of the amount needed for

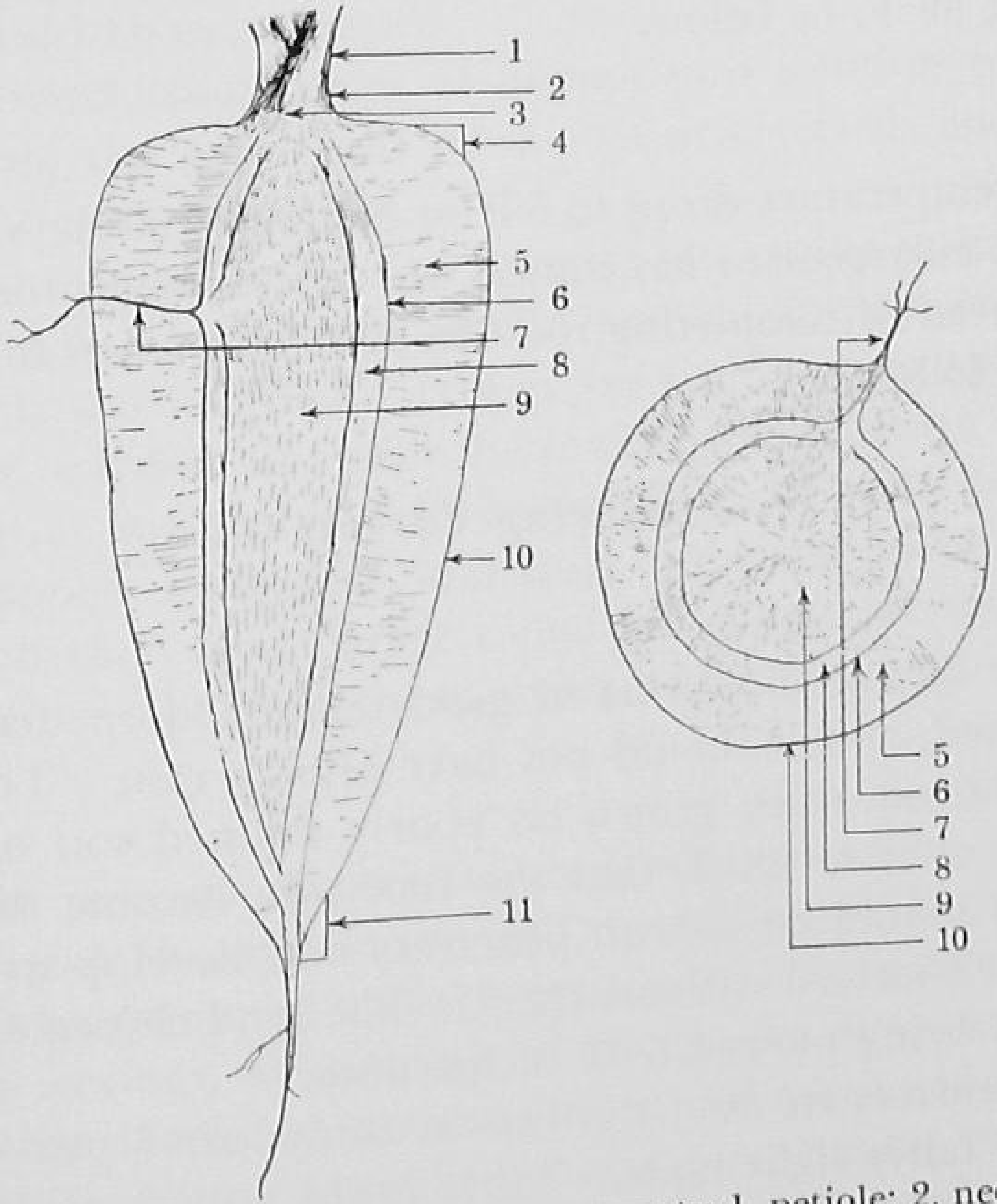

FIG. 17. Diagrammatic illustration of carrot parts: 1, petiole; 2, neck; 3, collar; 4, crown or shoulder; 5, phloem; 6, cambium; 7, secondary rootlet; 8, endodermis; 9, core, stele, or xylem; 10, periderm; 11, tip or base.

maintenance. Any factor that governs leaf size or efficiency affects root weight, though factors governing leaf size do not always similarly affect root size. The best temperature for root

growth is 65–70°F., which is lower than for leaf growth. Larger Chantenay roots develop at 66°F. than at 76°F.

Any deficiency or unfavorable growth condition that greatly reduces the tops usually reduces the amount of root. But under specific conditions certain elements, e.g., phosphorus, potassium, magnesium, and copper, increase root yields without materially affecting size of tops.

Germination

Environmental factors, e.g., rainfall (soil moisture) and temperature, affect the rate and percentage of germination. When a heavy or dashing rainfall and drying winds follow seeding, a hard crust is formed on some soils, which impedes and sometimes prevents emergence of the seedlings. Carrot seed does not germinate at 39°F. or below.

Bolting

If the temperature drops to 50° or below for 60 days or longer after root enlargement has started, the plants may produce seedstems instead of completing root development when higher temperatures follow.

Producing Carrots

Soil

Soil for carrots should be of good texture, deep, fertile, and well drained, and it should not bake after a rain. The longer types of carrots when grown on poorly drained soil often protrude out of it so much that the root tops become discolored. The roots should be able to penetrate and develop evenly and become well formed without check. The land chosen should be capable of being plowed 8–12 inches deep.

Market carrots are mostly grown on sandy loams, peat or muck, and other fairly light types. Fairly rapid growth is desired, as slow-growing roots may be lacking in flavor, smoothness, and texture. Carrots for canning or dehydration may be grown on heavier soils, since shape is less important than in roots for market. Also, the heavier soils often provide greater fertility and water-holding capacity, and so higher yields. In areas where nematodes occur the soil should be free of these pests.

The best soil reaction is probably *p*H 6.0–6.5. On soils more acid than *p*H 4.5 the yield usually is only fair. The crop does well on alkaline muck if manganese sulfate is added, and both yield and color are improved when copper sulfate is applied on acid muck.

Manure and Fertilizer

A 10-ton yield per acre removes about 32 pounds of nitrogen, 18 pounds of phosphoric acid, and 100 pounds of potash from the soil. Fertilizer, or fertilizer and manure, should be applied to return at least these amounts. Applying coarse manure immediately before the crop is sown may promote prongy, rough roots. A site which was manured for a previous crop is desirable. Manuring and plowing in the fall preceding the planting of carrots should be encouraged.

Carrots need 10–25 ppm. of nitrate (soil solution concentration) during the first third of the growth period, and benefit from 25–50 ppm. thereafter.

Where carrots are subject to internal blackening or breakdown it may be helpful to apply borax,* perhaps 30 pounds per acre mixed with the fertilizer. It may be applied broadcast before seeding, or in bands alongside the rows of young plants. Though there may be no visible evidence of micro-element deficiencies (boron, copper, manganese, and zinc) in carrots grown on different soils, higher yield, larger roots, and better keeping quality sometimes are obtained by applying minor elements.

Seeding

Time of seeding. Protracted cold, wet spells soon after seeding may cause the seed to rot, and reseeding may become necessary, but the grower of an early crop takes this chance. Several successive sowings, at intervals of 2–4 weeks, help to ensure a continuation of tender, succulent roots. Weather and soil conditions are usually unfavorable for seed germination in midsummer. For storage, a good time to seed is in late spring, as the roots of medium size are more desirable than the larger ones that result from early sowing. With late seeding it may be wise to irrigate to germinate the seed and get the plants well started.

* Borax contains 11.34 percent boron or 17.49 percent boric acid; hence 8.8 pounds of borax, or 5.8 pounds of boric acid, provides 1 pound of boron.

Rate and depth. The seed is sown 2–4 pounds per acre and ½–¾ inch deep. A few seeds of turnip or radish may be sown with the carrot seed to mark the rows. These germinate quickly, and are removed at the first weeding.

Spacing of rows. The rows are spaced wide enough to accommodate the machinery, commonly 18–20 inches, or closer in smaller plantings.

Raised beds.[425] In the Southwest and similar areas, carrots are sown in raised beds. The beds are usually 4–8 inches high after smoothing and about 40 inches from center to center; both the raised portion and the intervening furrows are 18–20 inches wide. The beds are thrown up with a triple or double lister; later they are smoothed and seeded in one operation. A wide shoe attachment permits the seed to be sown thinly in a broad band 3–5 inches wide, gives the roots more space for growth, results in a minimum of malformed roots, and avoids a need for thinning.

Thinning

Carrots tolerate some crowding, but if they are too thick the shape and size are affected adversely. Once well established (soon after the tops are large enough to grasp) the plants (when thinning is practiced) are spaced to stand singly. Thinning is done by hand, preferably when the soil is moist enough so that there is minimum disturbance of the seedlings left. Carrots grown primarily for bunching in small, tender sizes may be thinned to 1 inch in the row, pending the first taking of roots. For larger roots, thinning is more severe at the outset, commonly to 2 inches apart. Care is taken to pull the roots rather than merely to break off the tops. Carrots for canning usually are not thinned.

Cultivation and Weed Control

The seedlings are delicate, grow slowly at first, and cannot compete with weeds. Cultivation during dry weather helps to prevent soil cracks along the row which expose the roots to the dry wind and cause loss of moisture, stoppage of growth, and damage to the roots. The crown should not be exposed, since exposure causes green discoloration which lowers the quality

of the roots. Working a little soil towards the developing roots is often, but not always, helpful in avoiding this condition.

Certain weed killers are very effective in carrot fields. (See Chapter 15.) After the weeds are eliminated from the fields and the carrots are 3–4 inches high, very little cultivation may be needed. But a lack of cultivation may result in a compact, unsuitable soil condition. In New Jersey and Pennsylvania large differences in yield between (*a*) cultivation and hand weeding and (*b*) oil and hand weeding and no cultivation, in favor of the former, have been reported.[178]

In some districts of California [425] it is customary to chisel at least three times before harvest. The chisel is a knife-like blade drawn 3–4 inches deep through the center of the bed. Each time the chisel is set deeper until a maximum of 6–8 inches is reached. This practice may promote better root shape.

Mulching

> For celery and cabbage, we use straw as it comes from the bale. For carrots or beets, we use straw put through a hammermill with 1½-inch screen; we put this on after the carrots and beets are thinned and weeded at the rate of 50 bales (40 pounds per bale) to the acre; it could be thicker. For radishes, we sow, then mulch, then apply 400 pound nitrate of soda per acre, and leave them alone until we pull them. For cabbage, we mulch every other row. We do this because too much straw would be hard to get under, plus the cabbage stumps, and if we put half as much straw to a row it would not be thick enough to hold back the weeds. For celery we use 240 bales to the acre. Most people think of mulching just to conserve moisture, but I think keeping the soil temperatures down is just as important in the summer. Also, in fertilizing, the mulch keeps the roots close to the top, and it appears that they would absorb the fertilizer easier.[437]

Irrigation [425]

Insufficient moisture will result in low yields. Excessive amounts of water may decrease yields by leaching out the nitrates, by forming a high water table that interferes with growth, by limiting the volume of soil available for root development, or by producing a detrimental alkali content in the soil.

In general, sands hold less available water per foot of depth than loams, and clays hold the most. Sandy soils exhausted of available water will hold ¾–1 inch of irrigation water or rainfall per foot depth of soil, loams 1–1¾ inches, and clays 1¾–2½ inches. If carrots obtain water from the soil to a depth of 4 feet,

the maximum amount of available water that the soil can hold is 3–4 inches for sands, 4–7 inches for loams, and 7–10 inches for clays. Since the crop begins to suffer from lack of moisture before it can remove all the available water from the soil, carrots should be irrigated when ⅓–½ of such water is exhausted from sands and ½–⅔ from clays. The top few inches of soil may have been dried by the sun to a percentage lower than will support the plants; hence they may take proportionally more water than the amounts given for the entire top foot of soil.

In the Salinas district of California 4–8 irrigations are applied. In the Imperial Valley 10–12 applications are made, or an irrigation every 7–10 days. In Arizona, the fall crop receives 8–10 irrigations and the spring crop, which develops much faster, 6–8. The amount applied is 18–25 inches in the Salinas Valley and 30–36 inches in the Imperial Valley and in Arizona.

Carrots should be irrigated before any wilting of leaves appears, since they may be able to obtain enough water to keep the leaves erect without having enough moisture to make the desired growth. But the color of the foliage tends to be darker than the medium green that indicates rapid development and adequate moisture. One plan is to examine the soil in the root zone by means of an auger or soil tube. Usually a soil is darker in color when it contains plenty of water than when the available water has been removed down to or even near the permanent wilting percentage.

Harvesting and Marketing

Early carrots for market are pulled when partly developed, bunched with tops attached, and tied, e.g., with "Twist-ems" (wire laminated between two narrow strips of tough paper); for shipment 60 bunches fill a western lettuce crate. When carrots are graded for shipment, roots ¾–1 inch in diameter are tied 8–12 per bunch, those 1–1½ inches in diameter 6–8, and larger ones with diameters of 1½–2 inches only 4–6.

In the West and Southwest [425] carrots are taken from the soil with a tractor-drawn lifter. It usually consists of two subsoiler shanks placed about 20 inches apart (the width of the bed) and connected by a horizontal blade with the leading edge low; it may be adjusted to any desired depth. In a modified lifter, the two subsoiler shanks are bent sharply inward at the lower ends

and are not connected by a steel blade. The curved or L-shaped subsoiler shanks act as a plow. The carrots are loosened from the soil and are easily pulled. It has the advantage of not cutting the longer roots in beds with carrots of markedly uneven length.

The tractor-drawn harvester (which also may be used for large plantings of onions and beets) picks from the rows, removes the tops, dirt, and stones, and delivers the crop to a platform.

For canning, harvesting begins when the cannery can handle the roots. One plan is to chop the tops off with a sharp hoe, plow them out, and pick them up. Carrots for storage are usually left in the ground until just before a freeze. Care should be taken to avoid injury to the roots; the tops should be cut off with a sharp knife.

When bunched carrots are shipped, they are washed, packed tightly in containers, and transported in refrigerator cars, or crushed ice is put in each package to keep them fresh, crisp, and attractive. Modern washing equipment consists of a long trough through which water is pumped speedily. The roots are dumped from the field crates into the trough and are floated by force of the water toward a hooded box, where they are carried up on a perforated draper and sprayed from two directions with water under pressure. Then they are taken on an endless belt past the packers, who place them in iced crates.

Containers

The chief western shipping container for bunched carrots is the Los Angeles crate, holding 4–6 dozen bunches. Topped carrots are usually shipped in 50-pound mesh sacks, and, in the East, in 1-bushel tub baskets or 16- and 24-quart splint baskets. Prepackaged carrots in 1-pound transparent sacks have met with favorable consumer acceptance; 72 such sacks may be shipped in the L. A. crate.

Storage

The usable period for carrots from a good common storage extends to late winter or early spring. Some varieties store better than others; e.g., because of its thin skin and fine texture Nantes does not store so well as Chantenay. Roots dug when the soil is dry in late fall usually keep better than those lifted directly from a wet soil. After digging, the roots are topped close to the

crown. They should not be left in a warm place even for a few days. Misshapen or injured specimens should be sorted out; the latter favor development of rots.

At 32°F. carrots lose less in weight than at a higher temperature, remain higher in sugar content, and retain more of their original carotene. They lose in quality in storage owing to slow loss of sugar in respiration. A relative humidity of 90–95 percent prevents withering. Topped carrots freeze in storage at 29.6°F. Bunch carrots may be stored for 1–2 weeks, if they are not crowded and are free from surface moisture.

Certain chemicals are useful to retard sprouting and to keep the roots firm (see under Potato).

Waxing

In store windows and other places conducive to shriveling, carrots wilt rapidly; if waxed they retain their freshness and flavor longer and take on an attractive gloss. (See Waxing of Rutabagas.)

Insect and Disease Control

The *carrot weevil* (white, legless, brown-headed grub 1/8–1/3 inch long) may cause young carrots to wilt and die. Carrots are tunneled near the crown with brownish, sawdust-like material. Control is to apply poison bait about 3 times, beginning in the spring and repeating at intervals of 2 weeks.

The *six-spotted leafhopper* is a small, gray, wedge-shaped insect 1/6 inch long, which flies up from the plant when disturbed. It does little direct damage but transmits a virus disease, *carrot yellows,* which causes yellow, bushy tops and hairy roots of poor quality. Control is to dust with rotenone or DDT at 7-day intervals beginning when the plants show in the row.

Carrot rust fly adults are very small flies with red eyes, a shining dark-green body, and yellow head and legs. They are active in early summer, depositing small, white, elongate eggs on the ground. Maggots hatch from these eggs and work into the roots where they complete their growth and tunnel in the roots. Many of the fibrous roots become rusty and die. The insect is serious in some peat areas. No satisfactory control is known. High gamma isomer BHC helps to some extent.

Bacterial soft rot is controlled to some extent by seed treatment with a mercury compound, and by a long rotation avoiding susceptible crops.

Leaf spots and *blights* can be controlled, if necessary, with copper or carbamate sprays.

BEET

Beets are grown for table use in nearly all home and farm gardens, in most market gardens, as a truck crop, and for canning. They are useful in a number of ways, over a long period. Early in the season the thinnings can be used as greens. A second stage is for bunching when the beets are 1¼–1½ inches in diameter; often this is a thinning process, the longer roots being removed. A third stage is the "baby beet" (1½–2 inch diameter). Fourth-stage beets of 2½-inch diameter are excellent for pickling and canning. Fifth-stage mature beets, 3–3½ inch diameter, are stored and used for several months after harvest.

The beet is not especially sensitive to extreme heat. It is also resistant to cold, but it will not withstand severe freezing. It attains its best color, texture, and quality in a cool season or climate. Under favorable conditions 30 feet of row will yield 50–60 pounds of beets, less (30–40 pounds) if harvested before they are fully developed, or more if they are left for late digging. In market gardens, yields of 300–500 bushels per acre are common, and, for the cannery, 10 tons.

History

The root beet is essentially a modern vegetable. Beets were well known in ancient Greece and Rome, but it was the leaves, not the roots, that were eaten. The Romans took the leaf-type beet with them to France, Germany, and England. The root as developed in Italy was of the long, carrot-like shape. In 1689, Vanslep described a beet growing in Egypt as turnip-shaped, very early, and sweet. This was afterwards taken to Europe, and from it may have developed Flat Egyptian, Bassano (an Italian variety which came to America via France and was long popular), and Early Red Round of Vilmorin's 1821 catalog. From these may have come Vilmorin's Early Blood Turnip, the progenitor of sundry American varieties.

Flat Egyptian reached this continent in 1868. Crosby Egyptian was selected from it to retain the earliness, increase the depth, and remove the roughness. Detroit Dark Red, the leading variety, was introduced in 1892 by D. M. Ferry & Co., Detroit, Mich., but is basically Canadian, as the original selections from Early Blood Turnip were made by a Mr. Reeves, Port Hope, Ont. All-America winners are: 1933, Ohio Canner; 1934, Perfected Detroit, Asgrow Wonder, Good for All, and Little Marvel; 1935, Asgrow Canner; 1938, Perfect Model.

Varieties

A. Flat. Flat Egyptian. (The modern type is thicker and not so flat as the older type.)

B. Short-top shaped. Flattened at top and bottom with rounded sides to square or rounded shoulder and conical or tapered base: Crosby Egyptian, Light Red Crosby (Strawberry Crosby, Ferry Crosby, Vermilion Crosby).

C. Deep oblate to round. Early Wonder, Green Top Early Wonder, Asgrow Wonder, Morse Detroit, Ohio Canner, Perfected Detroit.

D. Globular to oval. Detroit Dark Red, Good for All, Crimson Globe, Green Top Bunching, Asgrow Canner, Crimson King.

E. Half-long. Half Long Blood, Early Blood Turnip.

F. Long. Long Dark Blood (Long Smooth Blood), Lutz Greenleaf (Winter Keeper).

Detroit Dark Red is the chief main-crop beet; there are short-top and medium-top strains, the former being suited in general to shipping and canning, and the latter to bunching. Morse Detroit has smaller foliage and somewhat flatter roots that become round at a smaller diameter. *Perfected Detroit* has a larger neck and foliage, and shorter or more nearly round roots than Detroit Dark Red. *Good for All* is smaller than Detroit Dark Red and the leaves are narrower and smoother. *Ohio Canner* and *Asgrow Canner* are dark-red canning varieties.

Flat Egyptian is not of the best quality or appearance, but it is the earliest variety. *Crosby Egyptian* is an early, bunching variety, but it is not a good canner because of pale or light-colored zones in the product. *Asgrow Wonder* has a larger neck and foliage, and the flesh is redder with less pronounced zoning. In *Light Red Crosby* the bright red color of freshly washed or moist roots is very attractive, but the color of the cooked flesh is an unattractive light red or pink. In *Early Wonder,* because of the greater area of the smooth below-ground surface visible

when it is bunched, the roots often seem lighter and brighter in color than those of Crosby Egyptian. The foliage of *Green Top Early Wonder* and *Green Top Bunching* does not turn red or bronze as quickly as that of most other varieties, and so they show merit for bunching. *Long Dark Blood* may grow 16 inches or so long. It is more popular in Europe than on this continent.

Plant Characteristics

Root

The root is thickened as a storage place of reserve food for the following year's growth. The taproot of the beet and carrot (conical taproot) really includes as well as an upper portion of hypocotyl, a lower portion of true fleshy taproot, whereas in the radish (fusiform taproot, tapered at both ends) and turnip (napiform taproot) the swollen portion is entirely hypocotyl.

Variation in shape of individual roots within a variety is due both to hereditary and to environmental factors. The shape varies with the stage of growth (age and size) at which it is observed. In flat types, the very small roots are wedge shaped or long conic, and as they reach usable size (¾–1 inch) they become nearly round or short-top shaped because of faster horizontal growth. Growth in this direction continues faster than that in length, and as the root increases in diameter it becomes relatively flatter; i.e., the ratio of diameter to depth becomes larger as the root nears maturity. Flat Egyptian becomes increasingly lobed as it increases in diameter, because of the unequal growth of secondary cambiums.

In round varieties, the early stages involve an increase in diameter in relation to depth. This increase is greatest near the top of the root at the start and progresses toward the taproot. Thus, round roots are successively long-top shaped, short-top shaped, ovate, and round with increasing age and diameter.

Growth in length may actually increase the length of the root aboveground.

Flesh Color

Canners, like consumers, prefer a dark flesh color. Time of year at which the crop is grown, weather, stage of maturity, and

the variety, strain, or seed stock, all affect flesh color. There is an expression: "Plant late to make red beets redder." Heavy rains following a dry period during a season of increasing temperatures may result in poorer color; but rains in late summer or early fall when temperatures are decreasing may increase the intensity of color. An extra few weeks in the field in autumn,

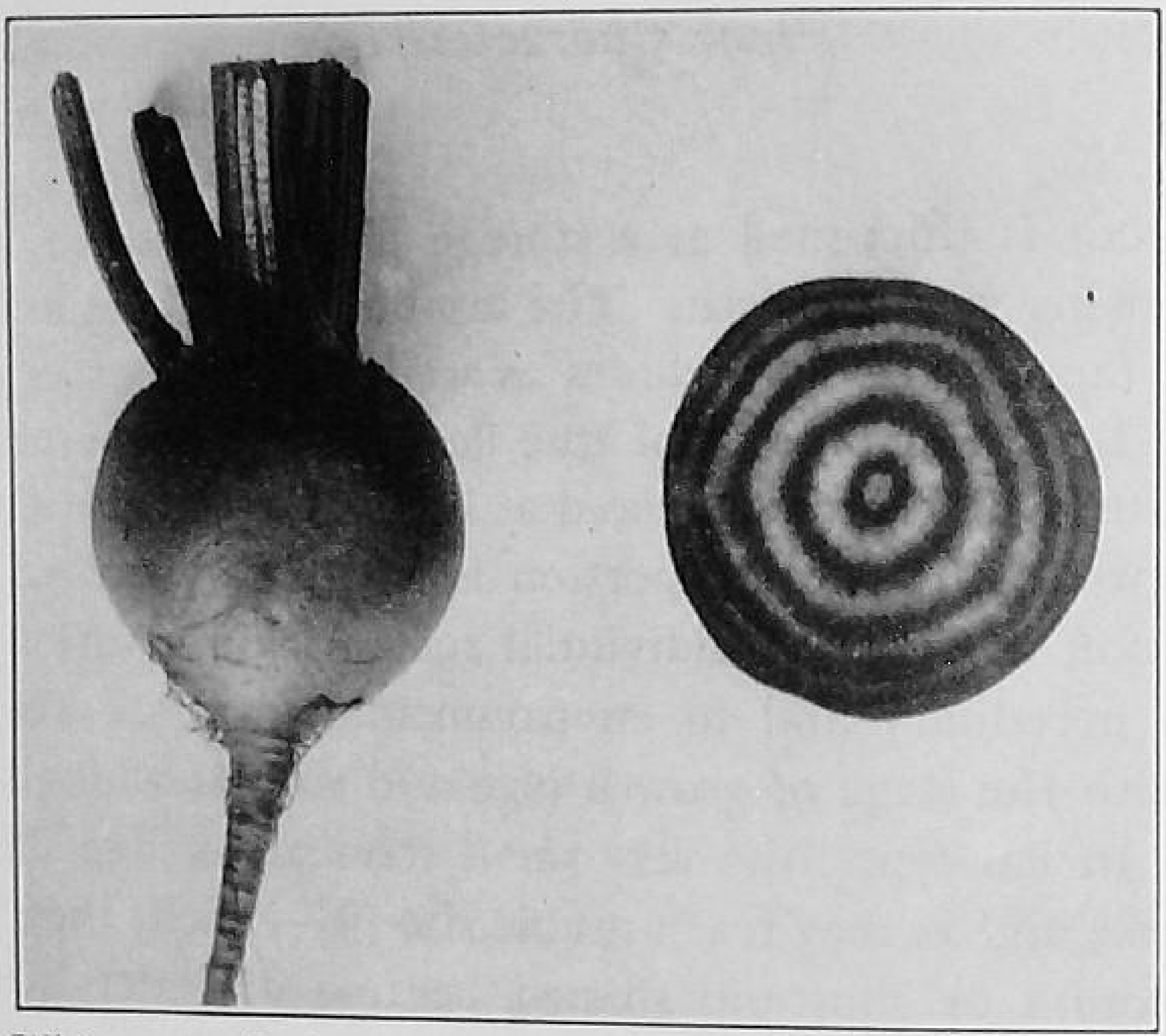

FIG. 18. White zones in beets are an undesirable feature but are common in early varieties and poor stocks.

with normal rainfall, also usually result in better-colored beets, probably because of the accompanying decrease in temperature. The largest roots in a harvest on any given date are usually the poorest in color.

A deficiency in any element or a lack of water that retards the utilization of carbohydrates in new growth may result in their accumulation and so increase pigment formation. Cool weather results in carbohydrate accumulation through a reduction in the rate of its use in growth and in respiration.

Producing Beets

Soil

Many soils are suitable as long as they are friable enough for proper development of the roots. A fine, smooth seedbed ensures

uniform depth of seeding and more even germination and facilitates cultivation and weeding.

A *p*H nearer 7.0 than 6.0 is preferable. Scab is worst on alkaline soils. When large amounts of manure are used the soil is buffered against the bad effects of high acidity. Even so-called high-lime crops like lettuce, spinach, onions, or beets will grow well in a *p*H of 5.6, provided a medium application of manure is made and enough nutrients and water are available. Beets produce well on alkaline muck if manganese sulfate is applied and on muck with a *p*H as low as 4.6 if copper sulfate is applied.

Manure and Fertilizer

Well-rotted manure, but not large amounts of fresh manure, may be applied to good advantage shortly before seeding. Green crops are useful to improve soil texture. Heavy soils can be made more friable, and sandy types will hold more water and bind better, if organic matter is incorporated.

A ton of beet roots removes about 5 pounds of nitrogen, 2 pounds of phosphorus, and 10 pounds of potassium from the soil; at least these amounts of the elements specified, plus the amounts used in the growth of the tops, should be returned to the soil in the form of manure, commercial fertilizer, or both. The best ratio and amount of fertilizer must be determined for each location.

Fertilizers that produce the largest yields also produce more succulent plants; i.e., they have more water per gram of dry matter and they lose it more slowly after harvesting. This fact is especially important to the shipper of bunched beets.

For the first two-thirds of the growth period 50 ppm. of nitrate nitrogen (soil solution concentration) is desirable, and thereafter low levels are sufficient. One application of nitrate at planting time can be adequate, and placement in a band 2 inches from the seed is more effective than a broadcast application. Analysis of juice expressed from leaf stems gives a good indication of the nitrogen supply.[357]

Sodium, as in nitrate of soda, or in sodium chloride when supplemented with nitrogen fertilizer, may sometimes supply a definite nutrient need of beets and result in a recovery of a normal-green foliage color as well as in more vigorous growth

and increased yield. The crop may also respond on muck to salt and occasionally to borax and copper.

In New York,[334] 500 pounds of common salt per acre or the equivalent amount of sodium in other compounds stimulates the growth and increases the yield. But if the pricing system for processing is based on a graded basis instead of a flat rate, only small beets may bring attractive prices. This raises the question of whether any fertilizer treatment that stimulates the growth of beets would be profitable or merely increase the yield of large beets which would bring a smaller return. Higher rates of seeding did not increase the total yields per acre but more desirable small-size beets resulted.[333]

Seeding

Germination. Beet seed may retain its viability 5–6 years, but, as a rule, it is not wise to sow seed that is more than 2 years old. The seed germinates well at 46–86°F., but best germination occurs at about 52°F. No seedlings emerge at 39°F.

Spacing. Beet seed usually is sown in rows 12–18 inches apart. Varieties with small tops, e.g., Flat Egyptian, may be spaced slightly closer than those with larger tops. For "baby beets," the spacing is somewhat closer than for roots for storage.

Time of seeding. The seedlings tolerate slight frost. Seeding in early spring often produces beets that are coarse in texture by harvest time in late autumn. Sowing at intervals of 2 weeks gives a supply of tender beets throughout most of the season. In areas where summer temperature may rise above a daily average of 80°F. it is wise to sow early enough to harvest the crop before such temperatures are current. Comparatively late seedings produce the best beets for storage, provided they are reasonably mature.

Rate of seeding. Commonly 4–5 pounds are sown per acre. Some growers sow an ounce of seed to 30 feet of row, others to 50 feet, and still others to 100–125 feet. The rate depends on factors such as size of planting, percentage germination, method of seeding, and market.

Depth of seeding. The seed is covered about 1 inch deep. A seed drill may be used, or 4–6 seeders can be attached to a tractor and drawn by it. To facilitate the use of a drill and

ensure a better distribution, the seed may be graded by screening with different-size mesh. (See also Coated Seed.)

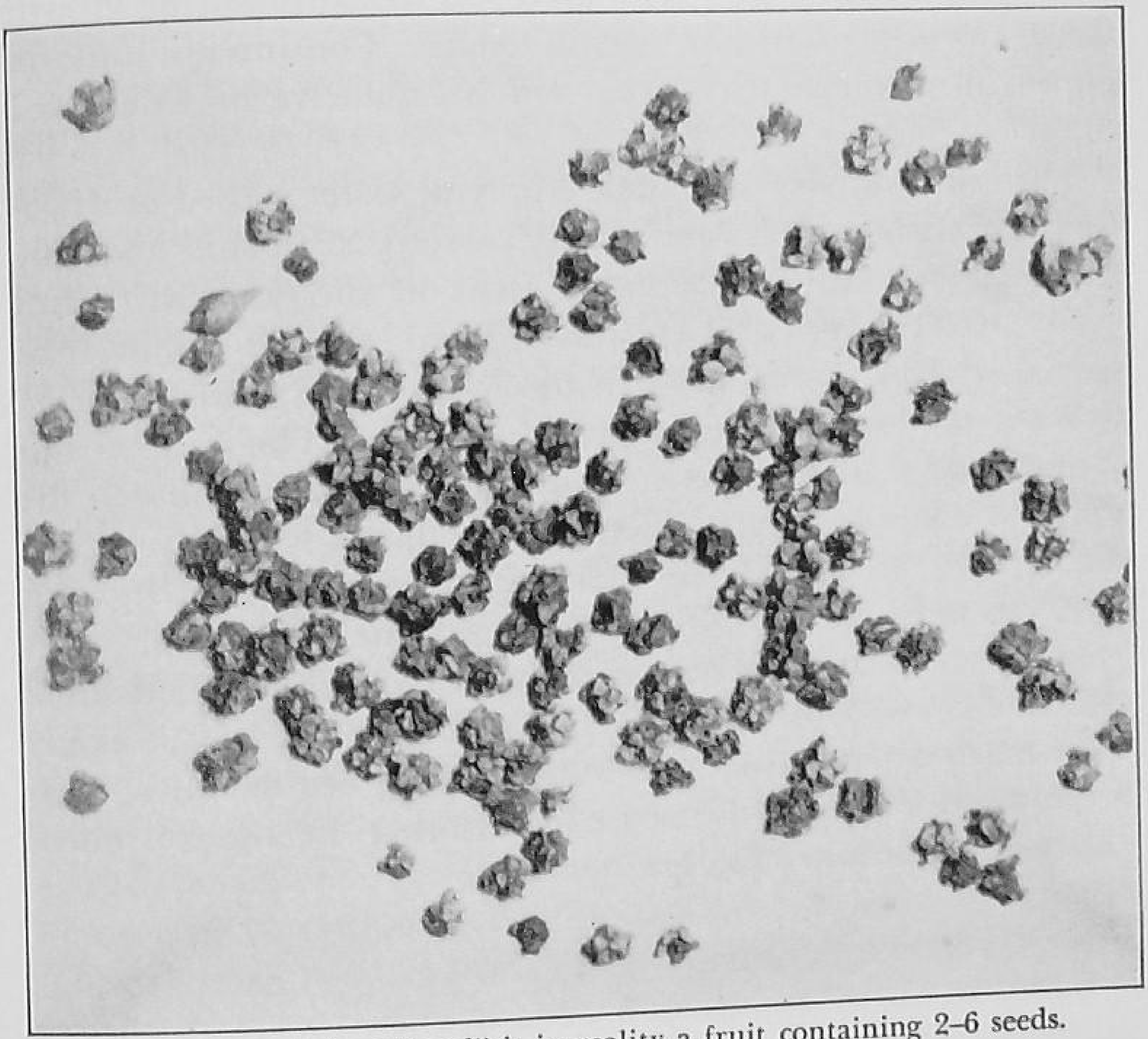

FIG. 19. Each beet "seed" is in reality a fruit containing 2–6 seeds.

PREMATURE SEEDSTEMS

If the plants are grown for a month or longer below 50°F., many of them bolt to seed.

THINNING

The "seed" is really a fruit consisting of 2–6 seeds, each of which may produce a plant. A germination of 150–200 percent is not uncommon. The plants emerge in groups no matter how sparsely the seed is sown (unless segmented seed is used). The first thinning should single out the plants in the group that have started together. The spacing may eventually be 2–3 inches apart in the row, depending on the purpose for which the roots are grown. Thinning is not practiced commercially as much as formerly.

Irrigation

Water serves as a solvent for nutrients in the soil and as a desirable cooling agent. With good soil moisture during growth the tissues of the beet root remain tender. Continuous, uniform growth in a comparatively cool soil is conducive to a deep red color.

The row or furrow method of supplying water is used in irrigation areas where beets are seeded in rows 22 inches apart by the sugar beet drill, or 28 inches apart by the grain drill with every 3 runs plugged. A cultivator, fitted with large shovels or special scufflers, is run through the rows before each irrigation to shove the loose top soil toward the plants. The water is run through the shallow furrows rapidly at first so as to moisten the soil, and then the stream is decreased so that it will only trickle, for at least ¾ hour. This practice encourages the irrigation water to meet the moisture normally present in the soil.

Sandy soils take up water quickly and irrigation is done more rapidly than on slow-soaking loams or clays. But on the sandy types much organic matter, such as farm or green manures, must be supplied if irrigations are frequent; otherwise the soil nutrients will leach away rapidly.

Harvesting and Marketing

Bunch or "baby" beets are harvested when 1¼–1½ inches in diameter. Beets for bunching are pulled by hand, the dead and injured leaves are removed, 4–6 roots are tied together, with tops on, and the bunches are washed to remove any adhering soil.

Beets to be stored for winter use must be reasonably mature when harvested. Immature roots may store poorly, sprout soon after they are stored, and develop a poor flavor. The roots will stand some frost but should not be left in the ground too late. The late crop is pulled by hand or loosened with a special plow. Then the roots are topped ½–1 inch above the crown or twisted off 2–3 inches from the crown.

In Oregon,[96] the machinery cost is far more than offset by lower labor needs. The harvesting cost per ton (pulling, topping, and loading) is several times less with the mechanized method than by hand. Yield probably has more effect on the cost of producing a ton of beets than does any other single factor.

Yield is particularly important because high yields can be obtained with very little more cost per acre than low yields.

Waxing

If not waxed (see Rutabagas), beets lose water rapidly in the air of a retail store or home cellar. The small amount of wax on beets that are cooked with the skins left on rises to the top of the boiling water and mixes so thoroughly with the foam that it is poured off readily with the cooking water. Waxing is of little significance where bunch beets have superseded topped beets on the market.

Canning

The interior color should be a deep red. Roots to be canned whole should be 1½ inches or less in diameter, uniform in size, and round or oval. When canned whole at 1½ inches diameter, beets are peeled and processed in a light syrup.

In dicing, it is not so essential to have small beets, though they should not exceed 2½ inches in diameter; large beets tend to be coarse and poorly colored. The roots are cut into cubes about ½ inch on a side by a dicing machine. Dicing requires a greater tonnage of beets than whole-canning, because more diced cubes or squares can be placed in a can. When whole beets are canned the number of roots used per can varies with the size of the can and the root but is usually 8–10.

Storage

The usable period for well-stored beets extends to late winter or early spring. Too young or too mature specimens do not tend to store well. Beets grown for storage are left in the ground until just before severe freezing weather in autumn. Roots dug when the soil is dry usually keep best. After digging, the roots are topped and placed in storage without delay. All injured specimens should be sorted out as they encourage rots.

The temperature should be 32°F. Storage in large piles should be avoided. The humidity should be high, 90–95 percent, to prevent shriveling.

Certain chemicals may prove very useful in delaying sprouting and keeping the roots firm (see Potato).

Bunch beets may be stored at 32°F. and high relative humidity for 10 days to 2 weeks, providing the leaves are free of surface moisture and the bunches are not packed so as to exclude air from the top.

Insect and Disease Control

Beet leaf miner (spinach leaf miner) larvae eat tissue between the upper and lower surfaces of the leaves and cause blister-like areas, thus weakening the plants. Controls are dusting with pyrethrum or parathion when the eggs first appear, and destroying nearby lamb's-quarters, chickweed, and plantain.

Beet webworm caterpillars eat the buds of young tender plants and often cover the feeding surfaces with webs. Dusting with pyrethrum is a good control. *Flea beetles*, which eat small holes in the leaves of seedling plants, are controlled by dusting with rotenone.

Leaf spot appears as circular brown or gray spots with red borders. Plowing under the old leaves in the fall and crop rotation help, as do copper substances applied when spots appear and thereafter at 10-day intervals.

Rhizoctonia root rot affects the crown of the root. The base of the stems of the leaves turns black and the leaves collapse and die. The fungus often penetrates the crown of the root causing the flesh to become brown and the skin to crack. Rotating beets with onions, sweet corn, peas, and other resistant crops lessens this trouble, especially if the soil is well drained. Potato, tomato, or lettuce should not be grown in this rotation as the same fungus affects them.

Dusting the seed (see Table 5, Chapter 15) helps prevent damping-off and seedling root rots. Internal breakdown, heart rot, or blackheart may be prevented by boron applications (see Index).

RADISH

The radish is a cool-season crop; is adversely affected by hot, dry weather; and remains in prime condition only a few days. To be mild, tender, and attractive, it must be grown rapidly and with plenty of moisture. If checked, it becomes hot, tough, and pithy.

Yield is about 20–25 bunches (8–12 roots per bunch) for 30 feet of row. Commercial growers harvest about 3,000 dozen bunches per acre for the first or early crop. Under favorable conditions, as on soils of high organic matter content in comparatively cool districts, 2,000–2,500 dozen bunches are harvested per acre for the midseason crop, and about 3,000 dozen bunches for the fall crop. Thus commercial growers may harvest a total of 7,000–8,000 dozen bunches, or even 9,000 dozen bunches, per acre, of the quick-maturing, short- to medium-foliage type, during the outdoor season.

The late types are not so well known, so widely planted, or so well liked as the early types. The late types are harvested in autumn and may be stored. They may be cooked much as turnips are cooked.

History

The radish probably came from central and western China, and India, where it was used as food long before recorded history. Wild radishes exist in the Mediterranean region. The radish was grown and highly prized by the Egyptians at the time of the Pharaohs and by the ancient Greeks.

Classification and Varieties

A. Early or spring type. Comparatively mild, quick-maturing, reaching edible maturity in 24–30 days.

- 1. Round-, globe-, or turnip-shaped.
  - (*a*) Entirely red.
    - (i) Short to medium top: Cavalier, Comet, Cherry Belle, Scarlet Globe Forcing, Buccaneer.
    - (ii) Long top: Scarlet Globe, Saxa.
  - (*b*) Red top, white base: Sparkler, Scarlet Turnip White Tip.
  - (*c*) Entirely white or yellow: Box, Golden Globe, White Turnip.
- 2. Half-long-, olive-, or oval-shaped.
  - (*a*) Entirely red: Early Deep Scarlet Olive, Half Long Scarlet.
  - (*b*) Red top, white base: French Breakfast.
  - (*c*) Entirely white: White Rocket.
- 3. Long.
  - (*a*) Entirely red: Long Scarlet.
  - (*b*) Red top, white base: Long Scarlet White Tip, Cincinnati Market, Wood's Frame.
  - (*c*) White: Icicle, White Vienna, Pearl.

B. Summer type. Larger and a better keeper than type *A*; mature in 30–48 days.

1. Round-, globe-, or turnip-shaped. White or yellow: Yellow Ball.
2. Half-long-, olive-, or oval-shaped. White: White Delicious.
3. Long.
   (*a*) Red top, white base: Chartier.
   (*b*) White: Long White Summer, Giant White Summer.

C. *Winter type.* Quite pungent, large; mature in 50–60 days, or more; planted so as to reach a desirable size in autumn, when they may be stored and will keep for several months under good conditions.

1. Round-, globe-, or turnip-shaped.
   (*a*) White: Sakurajama.
   (*b*) Black: Round Black Spanish.
2. Half-long-, olive-, or oval-shaped. Black: Half-long Black Spanish.
3. Long.
   (*a*) Red: China Rose.
   (*b*) White: China White, Nerima, California Mammoth White.
   (*c*) Black: Long Black Spanish.

In general, red varieties are preferred. It is difficult to make selections based on evidence of decided superiority without knowledge of where the seed has been produced, the conditions and care under which it is to be grown, and a number of other factors. The leaders in the early or spring type are *Scarlet Globe* (Cavalier, Comet), *French Breakfast, Scarlet Turnip White Tip* (Sparkler), and *Icicle. Cherry Belle,* introduced by A. R. Zwaan & Son, received an All-America award in 1949.

Plant Characteristics

The swollen hypocotyl constitutes the chief edible portion. The limited development of lignified vascular elements and the differentiation of abundant thin-walled parenchyma from the cambial derivatives account for the succulence of the edible root-hypocotyledonary axis. The relative proportion of root is greater in the half-long or long types than in the globe type. The red color is due to anthocyanin in the pericyclic cells.

Producing Radishes

Soil and Fertilizer

Best results occur when the soil is light, rich, moist, and friable. Radishes grow well on fairly acid soils. Well-rotted manure or readily available fertilizer often encourage a desirable quick growth. Fresh manure should not be used just before seeding.

Seeding

The seed may be sown in the spring somewhat before danger of frost is over, as soon as the soil is workable. Several successive sowings lengthen the season.

Radishes are grown successfully on muck soils throughout the growing season, using only large-size seed of the short- to medium-foliage varieties or strains. The fact should be borne in mind that radishes cannot be produced successfully on all sites and that the midsummer crop is risky. In most gardens, if sowings are made so late as to bring maturity into the warm, dry weather of midsummer, the radishes ordinarily become pithy or infested with maggots.

Another practice is to sow the seed late enough in the summer so that root development occurs in the cool, fall weather. Again, soil-moisture conditions at seeding time must be favorable for a satisfactory crop.

Fall seeding may be done successfully where irrigation can be practiced, or when there has been adequate rainfall, temperature conditions are favorable, and the portion of the growing season that remains permits the desired development of the radishes.

Some seeding is done in frames in both spring and fall for comparatively early and late crops, respectively.

The seed is sown about 1/4 inch deep. Deeper seeding often leads to off-type roots and to many plants that form useless roots. In the same variety, seed sown shallow produces roots that are comparatively round, whereas those from deep seeding are more elongated than is normal. To seed an acre with rows 12–18 inches apart requires 10–12 pounds of seed.

Harvesting

Harvesting starts when the roots reach edible size. The spring varieties become strong and pithy if not harvested soon after they reach edible size. They are pulled by hand and tied in bunches. The roots are washed to remove the soil and to give them a fresh appearance. When radishes are shipped ice is usually put in the package.

Winter radishes require the same storage conditions as carrots and should keep in good condition for 2–4 months at 32°F. and a relative humidity of 90–95 percent.

Insect and Disease Control

Maggot damage is checked by treatment with lindane. Dusting with rotenone or DDT controls *flea beetles.* Radishes are so easily grown that disease control measures are seldom necessary. If it seems essential to do so, the seed can be treated with Fermate, Arasan, or Semesan as a protection against damping-off and black root.

PARSNIP

The parsnip is a long-season crop. Among its merits are: its characteristic culinary qualities; the ease with which it can be kept for late-winter and early-spring use, when the list of available locally grown vegetables may be small; and, since the seed is sown directly outdoors, the elimination of the need for hotbeds or greenhouses for starting plants. Among the drawbacks are the frequent difficulty of securing a good stand, as the life of good seed is short, and the rather limited demand; also, the crop occupies the land all season.

The origin of the parsnip centers in the eastern Mediterranean area. It has been used for food from an early period, and was known to the ancient Greeks and Romans.

Classification and Varieties

A. Roots long (12–24 inches). Crown depressed or with high shoulder: Hollow Crown (All American, Champion, Success, Long Smooth, Maltese, Goliath, Model).

B. Roots medium long (10–15 inches). Crown rounded: Guernsey (Half Long), Student.

C. Roots short (6–8 inches). Crown full and rounded: Short Thick.

D. Roots rounded (3–4 inches deep). Crown full and rounded: Early Short Round.

Hollow Crown probably represent 75 percent of all plantings. It is 12–20 inches long, measures about 2½–3 inches across the depressed crown, and tapers gradually to a slender point. *Guernsey* is shorter and stouter, the crown is full rounded, and the roots are easier to harvest. These are the two chief main-crop and storage varieties. *Short Thick* is at least 2 weeks earlier than Hollow Crown, measures 6–8 × 2½–3½ inches, and is comparatively easy to pull.

Producing Parsnips

Seed Germination

Parsnip seed soon loses its vitality, and so only 1-year-old seed should be used. The seed germinates slowly. Rolling the soil over the rows or tramping it firmly after seeding hastens and improves germination in friable soils.

Soil and Its Preparation

Since the seed is slow to germinate, if the surface of the soil becomes baked before the plants can break through, a poor stand usually results. Heavy, stony, or lumpy soils make it difficult to secure a good stand and smooth roots. Coarse manure in direct contact with the roots may cause rough prongy roots. Land for parsnips is worked at least a foot deep, as shallow soil gives rough, misshapen, crooked, and branched roots. Parsnips produced on a well-drained muck which is not too acid in the underlying layers are commonly superior to those grown on mineral soil. Parsnips respond slightly to manganese sulfate on alkaline muck, to copper sulfate on acid muck, and often markedly to borax on all types of muck.

Seeding, Cultivation, and Thinning

Early sowing is essential for maximum yield, because the crop needs a long season. There must be good soil moisture at seeding time. Since the seed germinates slowly, if the soil is cool or dry it may not come up at all. The seed is covered ¼–¾ inch deep. About 3–5 pounds are used per acre.

Cultivation should begin as soon as weed growth appears. It can start soon after seeding if radish is sown for guide purposes. (See Weed Killers, Chapter 15.) The seed may be sown rather thickly and the seedlings thinned to 2–4 inches apart in the row before the plants become too firmly established, or usually 5–6 weeks after seeding.

Harvesting

Young, tender parsnips may be pulled and sold in bunches with the tops on. About 4–6 specimens comprise a bunch, but the number varies with the size of roots and market custom. The short type is ready for harvest about 2 weeks earlier than the longer types.

The main-crop type of parsnip roots grows deep, often 10–12 inches or more. When a plow is used in digging it is run close to the row, the furrow is thrown away from the plants, and then the roots are loosened by pushing them toward the furrow. A sugar beet implement may be used in harvesting; it loosens the soil under the parsnips, leaving them in place and easy to pull. The roots are best in flavor if not harvested until after a sharp frost, because cool weather tends to increase the sugar content. But it is difficult to harvest them when the ground is frozen.

FIG. 20. There is no evidence that parsnip roots that have started to grow in the spring are poisonous. At this stage, however, the quality is poor and the food value low because the reserves have been used up in growth.

Some of the roots may be left in the ground until spring. If covered with a straw mulch just before freeze-up, they usually winter reasonably well, but, of course, they cannot be dug during winter in northern areas. In the spring, they are lifted before they start growth and, if not used immediately, are kept in sand in a cool place until needed. There are no poisons in parsnip roots at any time, but after those that have wintered in the ground start growth the reserve food is drawn upon and the quality becomes inferior.

STORAGE

Storage at 32° is best, both from keeping and quality standpoints. A relative humidity of 90–95 percent avoids wilting. Parsnips freeze at 28.9°F. in storage. They are not injured by slight freezing but should be protected from hard freezing.

Freezing is not necessary for the development of good quality in parsnips; a temperature slightly above freezing is the effec-

tive factor. Roots stored at 32–34°F. become sweet and of high quality more quickly than those stored in a common cellar or left in the field (a change from starch to sugar, mostly sucrose, takes place). Parsnips may be waxed as outlined for rutabagas. Certain chemicals may prove useful in delaying sprouting and keeping the roots firm (see Potato).

Insect and Disease Control

Control measures are seldom necessary to control insects and diseases in parsnip.

TURNIP AND RUTABAGA

Turnip and rutabaga (Swede turnip) are essentially cool-season crops. The rutabaga is grown more extensively in Canada than in the United States; about 3 million bushels, mostly from Ontario and Prince Edward Island, are shipped each year from Canada to the United States. It ranks higher than the turnip in drought and summer-heat resistance, but thrives best under conditions of ample moisture. The rutabaga is primarily a fall crop; the turnip is an early-summer crop in northern areas.

History

The turnip originated in (*a*) central and western China, (*b*) middle Asia (Punjab and Kashmir), (*c*) near Asia, or (*d*) the Mediterranean. It may have come from the wild *Brassica campestris* (mustard type) of Russia and Scandinavia. It ranked next to grapes and cereals as Italy's chief cultivated plant during the time of the Romans. Cartier sowed turnip seed in Canada in 1541.

Turnip rape and both white- and yellow-fleshed turnips have 20 chromosomes. Swede rape and both white- and yellow-fleshed rutabagas have 38. Rutabagas and others with 38 chromosomes have arisen as hybrids of members of the two groups, accompanied by chromosome doubling. All turnips, whether white or yellow fleshed, purple or green topped, owe their different characteristics to variation within the 20-chromosome group and not to crossing with rutabagas. Certain rutabagas and yellow turnips are resistant to club root, and this fact is sometimes said

to be proof that yellow turnips are hybrids of turnips and rutabagas, the yellow turnips getting their resistance from the rutabagas. But more likely it has been passed on to the rutabagas from their ancestors, the resistant turnips.

Classification and Varieties

A. Turnip or soft turnip. Root often disc-like or decidedly flattened, though ranging from spherical to elongated conical; little or no neck; a distinct taproot, and secondary roots arising only from it; leaves and petioles hairy, coarse to the touch, yellowish green, slightly lighter below, smaller growth habit, open centered; edible maturity reached in 42–80 days.

1. White-fleshed.
   - (*a*) Purple-topped.
     - (i) Flat: Purple Top Strap Leaf, Purple Top Milan.
     - (ii) Globe: Purple Top White Globe.
   - (*b*) Bronze- or green-topped.
     - (i) Globe: Green Top White, Green Globe, Green Stone.
     - (ii) Long: Cowhorn.
   - (*c*) White-topped.
     - (i) Flat: White Milan, White Flat Dutch, Norfolk.
     - (ii) Globe: White Stone, Quicksilver, Ward Gem.
     - (iii) Half-long: White Egg, White Gem.
     - (iv) Long: Lily White.
2. Yellow-fleshed.
   - (*a*) Purple-topped, globe: Aberdeen Purple Top.
   - (*b*) Bronze- or green-topped, globe: Aberdeen Green Top, Invincible, Amber Globe.
   - (*c*) Yellow-topped, globe to top-shaped: Yellow Globe, Golden Ball, All Seasons.
3. Foliage varieties: Flat Japan, Shogoin, Broccoli-Raab, Tokio, Seven Top.

B. Rutabaga or Swede turnip. Root larger than turnip and deeper from crown to base; mostly ovoid shape, though varying from flat to tankard; roots arising from the underside of the enlarged portion as well as from the fine taproot; rather prongy root condition; neck or crown prominent, thick, leafy; leaves fleshier, larger, and deeper-lobed than turnip, not hairy, covered with a bloom which gives a bluish appearance, whitish-green below; larger growth habit; edible maturity reached in 85–90 days; somewhat higher than turnips in digestible nutrients.

1. White-fleshed, bronze- or green-topped.
   - (*a*) Flat-globular: White Rock, Sweet German.
   - (*b*) Globe: Macomber.
   - (*c*) Elongated, ovoid, or tankard: White Neckless.
2. Yellow-fleshed.
   - (*a*) Purple-topped.

(i) Globe: Bangholm, Laurentian, Westbury (Canadian Gem), Champion, Perfect Model, Magnum Bonum, American Purple Top, Premier, Purple King, Acadia.

(ii) Ovoid: Masterpiece, Superlative.

(*b*) Bronze- or green-topped: Ditmars, Lord Derby, Haszard, Invicta, Empire, Kangaroo, Perfection, Hartley, Wilhelmsburger.

Some leading turnip varieties are *Purple Top Strap Leaf, Purple Top Milan,* and *White Milan.* The foliage varieties of turnips are chiefly grown for "greens." *Seven Top* and *Shogoin* are much grown in regions with mild winters, for fall sowing and spring cutting; Seven Top is sometimes called Broccoli-Raab and Italian Broccoli. Leading rutabagas are *American Purple Top* and *Laurentian.*

Color of Roots

The upper part of both turnips and rutabagas may be purple, green, bronze, yellow, or white. The purple varies in intensity of red, is either continuous or spotted, and is due to anthocyanin in the outer cell layers of the "bark." The green color is due to the chloroplasts in the outer parenchyma layers, and the yellow to the pigment in the walls of the peripheral cork cells. The lower part of both turnips and rutagabas is either white or yellow.

Producing Turnips and Rutabagas

Manure and Fertilizer

Rutabagas and turnips do not seem to need as much potash as most other root crops, but both need as much nitrogen and phosphorus. If manure is used it is applied the year previous to planting so as to avoid maggot injury. Manure often is supplemented with fertilizer. When no manure is used, 200–500 pounds per acre of a mixed fertilizer is desirable. It may be applied shortly before seeding, either by the broadcast or by the plow-sole methods. Another plan is to apply it in a strip on top of the rib or drill after leveling and rolling; or it can be applied from a fertilizer attachment on the seed drill or sown in a narrow strip in a furrow near the row of plants.

A good treatment for Shogoin foliage turnip in central Georgia

is 1,500–2,000 pounds per acre of an 8-8-6 fertilizer a little before planting, plus 150 pounds of nitrate of soda, or its equivalent, as a topdressing when the plants are 2 inches high.

For *brownheart* control, see later under Insect and Disease Control.

SEEDING

Since the true turnip does not thrive in hot weather, the seed is sown as soon as the ground can be prepared in the spring in northern regions; for a fall crop the seed is sown about 2 months before hard freezes occur. Rutabagas when sown very early in the spring may become strong in flavor and bitter. The aim is to produce roots of 3½–5 inch diameter that have made their growth during cool weather. The best rutabagas for table use are grown from seed sown late in spring or early summer. By the late seeding, damage to the young plants by flea beetles often is avoided. With rows 1½–2 feet apart, 1½–2 pounds of turnip seed are used per acre. Rutabagas are seeded in rows 2½–3 feet apart, and ½ pound of seed per acre is ample.

One of the following plans may be used to give a ½ pound per acre rate:

(*a*) Roast half the seed by placing it about 1 inch deep in flat pans in the oven for 2–3 hours at 300°F. A very hot oven might burst or char the seed. Place a few of the roasted seeds between wet paper for 2 days to be sure none can sprout. Mix the roasted seed with the live seed, half and half, by pouring back and forth from one container to another. Sow the mixture at 1 pound per acre.

(*b*) Set the fertilizer runs of a grain drill to sow 100 pounds of fertilizer per acre. Leave every fourth spout open. Thoroughly mix ½ pound of seed with every 25 pounds of fertilizer. If the drill cannot be set to sow this small amount uniformly, use more fertilizer with the seed. This small amount of fertilizer is used only as a means to obtain uniform distribution of the seed and does not fill the fertilizer requirement. Do not mix the seed and fertilizer until just before seeding or injury to the seed may result.

(*c*) Mix the seed with chick grit of the same size as the seed (14 cups of chick grit to 1 cup of seed). Sow with the grain drill set on finest adjustment of wheat size.

Seeding on the level is best where conditions may be dry. With raised rows, the crop may suffer more from lack of moisture, as there is a greater surface for evaporation. If ridging is done, 2–3 inches high is ample. Under irrigation, raised rows aid in

applying water and there is less danger from scalding due to water lying in the field.

Thinning

Germination of the seed is usually good. At first, groups of plants may be left where eventually only one will remain. These groups are later thinned to one in each place. Turnips should stand 3–5 inches apart, and rutabagas 6–8 inches apart, in the row.

Bolting to Seed

Sometimes the plants produce seedstems before the roots reach usable size. Difference in varietal response may be a measure of the amount of low temperature required for bolting; e.g., Shogoin requires little cold and Golden Ball more. Decrease in bolters from the later turnip sowings indicate that increased length of day is less important than chilling of the plants during early growth. Exposure to 50–55°F. is a factor in bolting in rutabagas.[300] Bolters resemble rape, and so growers may suspect them to be such and criticize the seedsman for selling poor seed. Bolters may be due to: presence of segregates of natural crosses of any two of Swede turnip, rape, and Swede-like rape; presence of strains of pure Swede turnips with a genetical predisposition towards bolting; environmental conditions which promote seed rather than roots. Early sowing sometimes results in bolting that is avoided by sowing 2 weeks later.

Tillage

A narrow-backed 6-inch-wide turnip hoe is preferable to the high-shouldered hoe for hand work. Moderately deep cultiva- tion may be given early in the growing season; as the plants get larger, cultivation should be shallow. When the leaves overhang the rows and there is danger of damaging the plants, cultivation should cease.

Harvesting

A desirable size to harvest turnips is 2–3 inches in diameter; larger roots commonly are coarse and bitter. Rutabagas will stand some frost, but the roots should be harvested before they freeze. The improved quality after exposure to frost is because

temperatures near the freezing point increase the sugar content of the roots. Harvesting is best done when the roots are dry and lift cleanly from the soil. There are implements that aid in harvesting, but most rutabagas are pulled by hand and trimmed with a butcher's knife. The tail end of the root is cut off 1–1½ inches below the butt, and then the small side roots are rubbed off with the back of the blade. The top is cut off with a single stroke, leaving ¼–½ inch of neck, but not cutting into the body of the root.

Once rutabagas are pulled, freezing or sunburning may ruin them. Forks should have knobs of sufficient size on the ends of the tines to prevent puncturing. Bruising of roots is avoided by placing bran sacks filled with straw under the chute for the first load and against any sharp edges in the storage bin.

Rutabagas keep 4–6 months at 32°F. and 90–95 percent relative humidity. They freeze at 29.5°F. No rutabaga should be more than 3 feet away from circulating air; i.e., roots should not be piled more than 6 feet deep in a bin with a slatted floor.

Turnip greens that are stored at 40°F. for 24 and 48 hours retain 95 and 86 percent, respectively, of their original ascorbic acid.[345] Those stored at room heat from 8:00 A.M. to 6:00 P.M. and at 40°F. from 6:00 P.M. to 8:00 A.M. retain 78 percent of their original content of ascorbic acid after 24 hours and 68 percent after 48 hours.

Certain chemicals may prove useful in delaying sprouting and in keeping the roots firm (see Potato).

Waxing

Rutabagas are waxed to avoid wilting in a dry atmosphere and to retain good quality and appearance in marketing. Some markets demand waxed rutabagas to the exclusion of untreated roots. The process is not designed for long-term storage, and it is unsafe to attempt bulk storage of the treated roots. But small lots, such as a householder might require, will keep well for up to 5 months in cool or cold storage. Temperatures which are too high will allow sprouts to form and may cause other more serious injuries.

The roots are washed, trimmed neatly, and allowed to dry. The washing should not be done in the drying room as the water would make the air damp. Much of the free water which

might drip into the pile of drying roots can be removed by rolling the roots over a gentle incline made of coarse sacking. Final drying is done in the drying room with the roots on slatted shelves. Overnight in a reasonably dry, warm atmosphere will give the desired dryness. As the roots dry the atmosphere becomes more and more humid, and in a small room the air may approach saturation before the roots are dry. The remedies

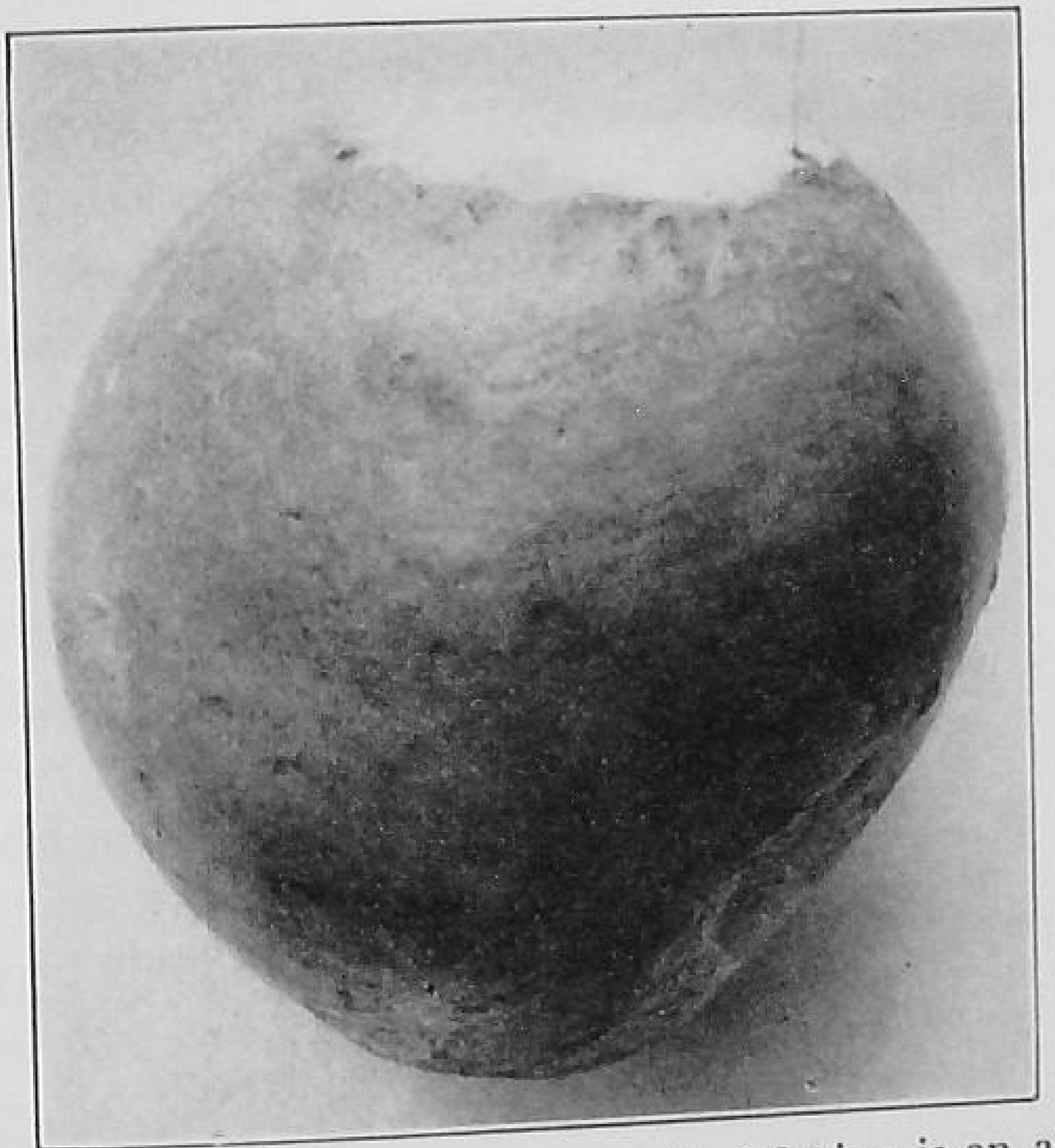

FIG. 21. Rutabaga root trimmed and waxed. Waxing is an aid to keeping quality under some conditions and improves the market appearance.

are: to warm the air (increase its water-holding capacity), to introduce fresh air (ventilation), or both. Fans and stoves aid in keeping the air moving.

Waxes that must be melted and used hot are more suitable for rutabagas than those used cold (colloidal waxes in water suspension). The "Canadian" or "hot wax" process results in less loss of moisture and saves time in drying. If a highly purified paraffin wax is used alone the coating on the root is too brittle. If 2–5 percent of mineral oil, Vaseline, or beeswax is mixed with purified paraffin wax the desired amount of flexibility results. The white or yellow form of crude scale wax needs no adulterant since it is not brittle, it costs less than the purified wax, and its appearance and durability on the root is good.

For each bushel of rutabagas, ½–¾ pound of wax is needed; the amount is higher for small roots or if the wax temperature is too low. The wax (or wax mixture) is melted in a metal container which is large enough to completely immerse the roots. Wax will burn, and care must be taken against fire. Overheating the wax may impair its quality. Best results occur with wax kept at 260°F. At lower temperature the coating on the root is too heavy, more wax is used per bushel of roots, and the appearance is dull and rough. If the temperature of the wax is too high, the root is burned, made unsightly, and soon decays.

Large-scale operators use various types of machinery in processing rutabagas. Mechanical carriers and elevators transfer the roots from one point to another. Most processors use mechanical washers, and some use a machine for dipping the roots in wax. Some operators use forks of appropriate type for handling the roots in the wax. The root must be completely immersed in the wax for about 1 second. Too long in the wax will burn the root.

Sometimes there is difficulty with rutabagas waxed early in the fall (during very active growth). Possibly high temperatures plus active growth cause so much carbon dioxide to be given off that the wax layer does not allow enough ventilation.

The finished product should be covered evenly with wax, the surface should be bright, and the wax should be so transparent that the root colors show clearly. Dull or opaque areas indicate places where the skin was too damp when the root was dipped in the wax.

Insect and Disease Control

The *turnip aphid* sucks the juice from the leaves. The leaves turn yellowish and the plants are dwarfed or die. If the attack occurs late in the season the roots often begin to decay with a foul odor. Control is applying nicotine or rotenone dust or spraying with 1 pound of linseed oil soap in 10 gallons of water. Parathion is very effective but must be used with caution for the operator and not applied later than 1 month before harvest.

The *turnip* or *striped flea beetle* does most of its injury during the first week or two after the seedlings have emerged. Control is dusting with DDT or rotenone.

Cabbage maggot, caterpillars, and *harlequin bug* may cause damage. For control, see under Cabbage.

Brownheart (dark center, water core, blackheart, raan, punky core) first appears in rutabagas as watersoaked, but firm, patches in the flesh. Severely affected roots may be off shape and have a rough, corky to leathery skin, or brownish and punky inside, particularly in storage. Finely powdered borax is the remedy, 10–15 pounds per acre applied alone or in a fertilizer. Application of borax before seeding is not successful on high-lime soils. Granulated borax, 20–30 pounds per acre, broadcast with a hand cyclone grass seeder after thinning, is another treatment. Borax can be sprayed effectively on the leaves when the roots are 1–1½ inches in diameter (8 pounds of fine borax, 2 pounds of bentonite clay which has been soaked overnight, and 50 gallons of water, per acre). Prepared dusts, 40–50 pounds per acre, especially if directed to the underside of the leaves, give good results.

CELERIAC

Celeriac is also known as turnip-rooted celery, root celery, or knob celery. In celery, the stem forms a mere basis to the

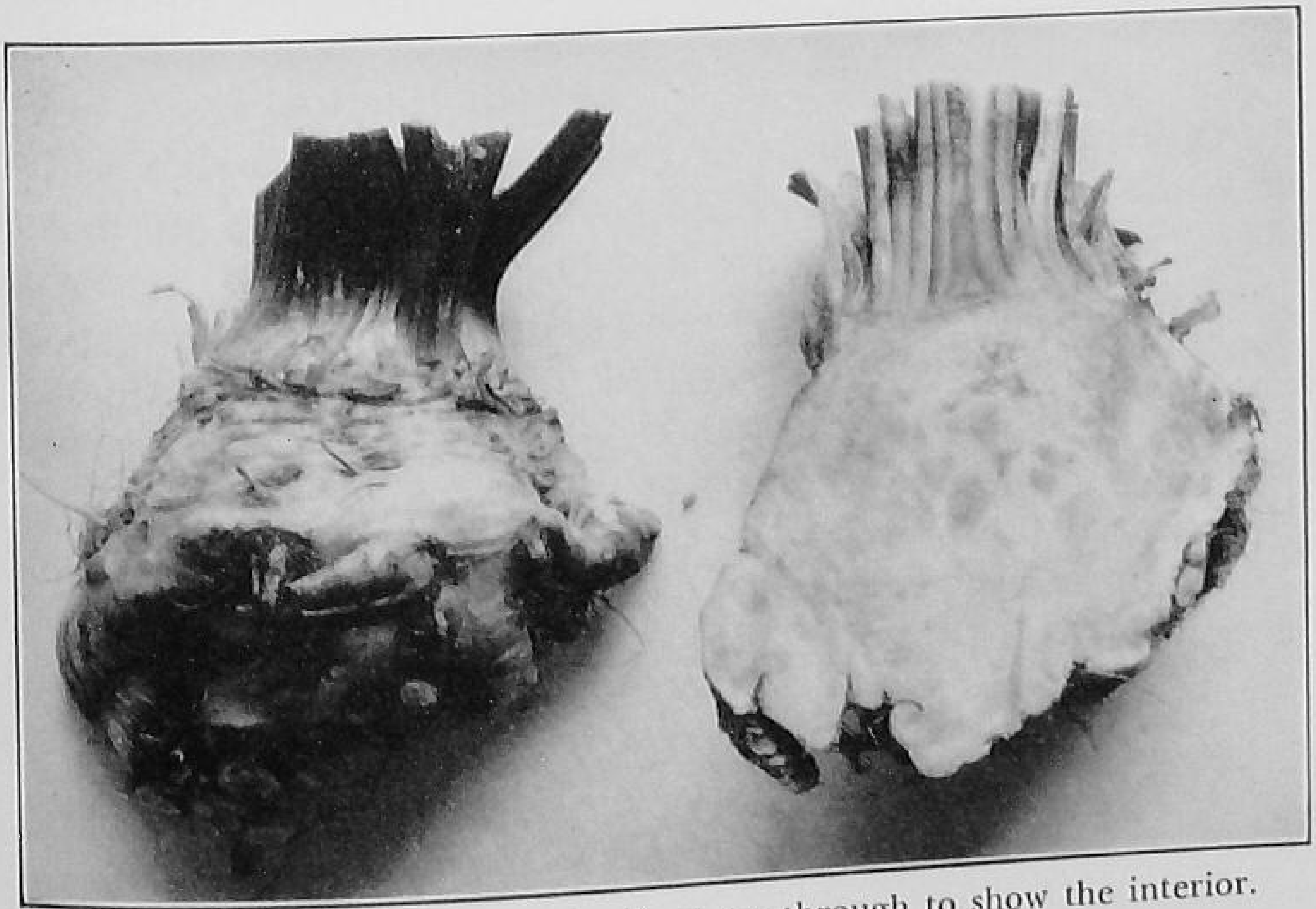

FIG. 22. *Left:* Celeriac. *Right:* Root cut through to show the interior.

leaves, but in celeriac it is developed into a knob that measures 2–4 inches across. The enlarged roots (which are true stems) are trimmed, washed, and boiled until quite tender. They may

then be pared, sliced, and served with white sauce, or left uncut to be sliced up for salads when cold. Many use celeriac in soups and stews.

Prague is the leading variety. Other varieties are *Delicacy, Apple,* and *Early Paris.*

Seed is sown and the plants handled much like those of celery. Good spacing is 8–12 inches apart in rows 1½–3½ feet apart. After planting, water should be supplied freely, or the roots may not attain best size and quality. The purpose of cultivation, besides weed control, is to draw the soil away from the plants at frequent intervals, because, providing they are not distressed, the more they stand out of the ground the better. The enlarged roots are lifted before freeze-up and stored in sand. Just before storing, the outer leaves are removed. Those in the center must remain, or the roots may waste their energies in producing another set.

5 · LEGUME OR PULSE CROPS

PEAS

Peas are probably as widely grown as any other vegetable in cool temperate regions and are included in nearly every home and market garden. They are one of the three chief canned-vegetable commodities, the two others being sweet corn and tomato. A large tonnage of fresh peas is preserved and sold frozen.

History

The pea is the only vegetable that can with certainty be traced back to the Stone Age; it was found among the relics at Morssedorf, Switzerland. Ethiopia is probably the main center of origin of the garden types.

The following varieties, many of which have attained great esteem in America, originated in England: Yellow Admiral, Advancer, Little Gem, Prince of Wales, Premium Gem, Telephone, Stratagem, Alaska, Gradus, Sutton Excelsior, Alderman, Daisy, Thos. Laxton, Little Marvel, Laxtonian, Lincoln, Hundredfold, Superb, Giant Stride, and Progress.

In America, the Associated Seed Growers, Rogers Bros. Seed Co., Washburn-Wilson Seed Co., Crites-Moscow Growers, Gallatin Valley Seed Co., U. S. Department of Agriculture, and Wisconsin Agricultural Experiment Station have developed many of the leading varieties.

Varieties

A. Home and market garden varieties.

1. *Early:* Progress, World Record.
2. *Early midseason:* Climax, Cody, Glacier, Gradah, Gradus, Laxtonian, Teton, Thos. Laxton, Wando (for the South).
3. *Midseason:* Hundredfold, Lincoln, Little Gem, Little Marvel, Morse Market, Multifold, Nott Excelsior, Premium Gem.

4. *Late:* Alderman, Aldermah, Duke of Albany, Giant Stride, Stratagem, Stratah, Telephone, Wyoming Wonder.

B. *Commercial canning varieties.*
1. *Alaska group:* Alaska, Alah, Yukon, Superlaska, Supergreen, Alaska Supreme.
2. *Early Sweet group:* Alsweet, Surprise, Wisconsin Early Sweet, Early Harvest, Ace, Mammoth Early Canner.
3. *Midseason Sweet group:* Early Perfection, Pride, Bonneville.
4. *Late Sweet group:* Perfection, Signal, Bridger, Perfected Wales.

C. *Freezing varieties.*
Suitable varieties for freezing include Alderman (except in small sizes), Aldermah, Cody, Freezonian, Glacier, Gradus, Laxtonian, Miracle, Perfection, Dark Green, Progress, Shasta, Statagem, Stratah, Teton, Thos. Laxton (dark-podded strain), Topper, Wando, Wyola.

Plant Characteristics

Roots

Nodules may be formed on the roots by nitrogen-fixing bacteria which move very slowly, if at all, in the soil, though they may be spread by rain and tillage. As the tip of the root hair pushes through the soil, it may come into contact with the organisms. These cluster at the top of the root hair, dissolve the cellulose of the wall, and thus enter the root hair (see Inoculation, later).

Pod

The development of the palisade layer, which may become very hard, affects tenderness and succulence. Nucellar tissue is absent in the mature seed and also in the endosperm, which is entirely absorbed by the growing embryo after 2 weeks. Prior to this, the endosperm is important in the nutrition of the developing embryo and contributes to the sweetness and tenderness of the pea until it is more than half grown. Dark-green-podded varieties retain their fresh appearance longest.

The pods of edible-podded peas lack, at all stages, the fibrous, indigestible, inner, parchment-like lining of the valves (the endocarp) which makes the pods of other peas, even when boiled, hard to masticate or digest. Also, the mesocarp becomes thickened, fleshy, and juicy, giving "body" to the pod unlike the

thin, shell-like structure of the pods of other peas. They may be eaten like the pods of snap beans.

Seed Coat

The mature seeds are either smooth or wrinkled. The thin coat consists of three layers of outer integument, two of which are but one cell thick and the third several cells thick. Seeds of certain varieties, e.g., of the Alaska group, may be called blue, as they generally are in England, or green, depending on the observer. In some strains the seed coats separate more completely from the underlying green cotyledons than in others, and the intervening layer of air causes the peas to appear white just as in the cream-seeded types similar differences in the amount of separation lead to salmon-colored cotyledons, or to almost white peas where the layer of air shuts out the underlying color.

Producing Peas

Climate

Yields are usually higher and the quality better when the crop matures under cool conditions. Peas are usually sown as soon as the soil can be properly worked. They do not thrive well after the dry, hot weather starts. The seed germinates well and the plants make vigorous growth at colder temperatures than those suitable for many other vegetables. The plants are not greatly damaged by moderate frosts. A temperature that will not injure the plant may occasionally kill or greatly retard blossom and pod development.

Hardiness of wrinkled versus smooth peas. There has been a deep-seated belief that smooth-seeded peas are hardier than wrinkled ones, less likely to rot if heavy rains occur before the plants emerge, and, therefore, the best for early sowing when the soil is cold. If there is this difference in susceptibility of the seed to rotting in the soil, it may be due as much to varietal factors like sugar content as to the fact that one type is smooth and the other wrinkled. The fact must not be obscured, though, that, when sown under cold, wet conditions, not many of the early, wrinkled sorts, unless treated with a seed protectant such as Spergon, will germinate as well as Alaska.

TEMPERATURE AND MATURITY. If two lots of the same variety are sown several days apart, under similar conditions, they may bloom almost together and be ready for harvest at almost the same time, especially in areas with high temperatures in late spring and early summer. The late sowings may yield less than earlier ones and be of inferior quality.

SOIL

Sandy or gravelly soils result in early crops, but plants on such soils often suffer from drought if water is not supplied. In areas where excess evaporation occurs the usual spring practice is to hitch a harrow behind a plow so that the soil is worked down to a fine tilth immediately. This helps reduce moisture loss and also avoids lumps. Success or failure in two adjoining pea fields may depend greatly on the care given the soil before seeding.

The seedbed should be thoroughly prepared, about 2½ inches deep, especially if the seed is drilled in close rows (e.g., for the canning crop), since in this method no cultivation can be given after seeding. A fine, well-prepared seedbed is essential for even germination, a full stand, and uniform maturity. For canning, fields that are quite smooth and uniform in soil type should be chosen. Plants growing on knolls mature their crop earlier than those in depressions or hollows, so hilly fields produce undesirable uneven maturity.

The pea plant draws heavily on the soil for nutrients, and, despite its nitrogen-fixing capabilities, it is an exhausting crop. For this reason, and as the time between seeding and harvesting is short, the land must be well prepared to enable the roots to spread freely and collect rapidly the nutrients required.

Peas do not thrive well in a highly acid soil. A good range is between *p*H 5.5 and about *p*H 6.7 or slightly higher. Soils showing alkali deposits should be avoided.

MANURE AND FERTILIZER

Plowing under a clover or other green-manure crop helps maintain soil fertility and desirable texture. Pea vines or refuse should not be used as humus-building material if they carry disease. The vines may be made into silage, fed to livestock, and recovered as manure.

For midseason and late crops in particular, considerable well-rotted manure, worked in fairly deeply where the roots can find abundant nutrients when the pods begin to fill, is advisable. Simply enriching the top soil layer may have adverse effects. When the young plants find nutrients near at hand, the roots may not penetrate as deeply as desired.

Peas gather or fix nitrogen and so help to improve the land. But peas for canning are cut before complete plant development is reached, and so they may not be able to fulfill the nitrogen-collecting function. Adequate available nitrogen in the soil helps the young plants to grow quickly.

Fertilizer tests on peas usually show a good response to phosphorus and potash, the best rate varying with the site but commonly being 300 pounds of superphosphate per acre; 300 pounds of a 0-20-20 fertilizer supplies 60 pounds P_2O_5 and 60 pounds K_2O per acre. An abundance of potassium tends to lessen the absorption of calcium. The chloride and the sulfate in potash fertilizers are of equal effect on quality when peas are harvested at the proper stage, but the chloride form of calcium makes harder peas.

A fertilizer ratio similar to 1-1-1 such as 8-8-8 or 9-9-9 seems good for processing peas.[180] The increase in yield of peas due to the fertilizer tends to be in terms of larger peas rather than more numerous peas.

The method of application is important. It may be better not to use fertilizer containing nitrogen or potash at all than to apply it in contact with the seed. Predrilling fertilizer is a common practice with peas.

Root rot and fusarium wilt may make it unwise to sow peas on the same land (except perhaps in the West and with resistant strains) oftener than once in 4–5 years. Good yields usually occur when peas follow a cultivated crop. The pea aphid winters and subsists the rest of the year on various types of legumes. It may be wise, therefore, either to arrange the rotation so that the pea land is not near those legume crops or to harvest such crops early.

Inoculation

Inoculation is inexpensive and simple (directions accompany the culture). It is likely to increase the yield and improve the

grade when peas are sown for the first time on land that has not been used for legumes, when they are grown on rather acid soils, and when the soil lacks fertility. Neutral and fertile soils tend to keep the desirable strains of pea nodule bacteria more effectively than less fertile and acid soils. Treatment for seed-borne diseases (see Chapter 15) may affect the benefits from inoculation (by killing the inoculant) and is often the better practice.

Seeding

Selection of seed. Seed that germinates less than 90 percent in laboratory tests usually produces poor stands in the field. Soaking the seed in water is of doubtful value; the stand and vigor of the plants may be reduced, owing to the leaching out of soluble-food reserves and starch-digesting enzymes. Growers of canning peas usually are supplied with seed by the canner. It is in the interest of the canner to provide good seed. Precaution should be taken to guard against mixing early and late varieties.

Time of seeding. In general, the later in spring the seeding date the lower the yield and quality (see Climate).

Rate and depth of seeding. When pea seed is sown too deeply the peas often come up slowly, rot, and the stand is poor. A good depth is about 1½ inches on the heavier soils, and 2 inches on lighter soils.

The usual rate of seeding is 4–4½ bushels per acre. As much as 5–10 percent of the seed may be injured in a force-feed grain drill, especially if a protectant that roughens the seed is used. This injury is avoided by using 1 pound of graphite to 1 ton of seed. The treated seed passes through the drill 30 percent faster than untreated seed, and so the rate of spread of the drill must be adjusted. Seed treated with Spergon (which does not roughen the seed) and sown at the rate of 3 bushels per acre may yield as much as, or more than, untreated seed at 4–5 bushel rates.

Vine Support

In the home garden, supporting tall vines has these advantages: facility in controlling weeds; increased pickings; more attractive pods; good exposure of the pods, making it easier to select those in good condition for harvest; and less damage to the plants in picking. Staking, when practiced, must not be unduly deferred, as results are seldom satisfactory once the stems

have become bent. It is wise to earth up the rows a little when the plants are about 3 inches high. Bushy twigs about 18 inches high are placed on each side of the row and supplemented with stakes or poles at least a foot taller than the variety apparently needs. No attempt should be made to construct an impenetrable fence, for peas need abundant light and air, but wires are sometimes used as a trellis.

Market growers, in general, find that the labor and expense involved in the use of supports is not justified, and so very few large growers in the East use them. But in Washington State tall types are trained to poles, twine, or mesh, and the peas produced sell at a premium in the East.

Cultivation and Weed Control

Peas for canning are drilled in rows close together and are not cultivated; hence good preparation of the seedbed is very important. Weeds in vines of canning peas put through the viner cause heating to take place more rapidly than is usual in a clean crop. When the peas are grown in rows spaced far enough apart to permit tillage, shallow cultivation helps to control weeds and to keep the soil surface loose and may be continued until the vines interfere. (See Weed Killers, Chapter 15.)

Irrigation

Furrow method. Shallow furrows are made between the rows with a scuffler. Low ridges of soil are shoved up against the plants so that the water will not puddle the soil around them. The water is then guided into the furrows quite rapidly at first so as to wet the soil, and then it is set so that it trickles slowly for ½–¾ hour per irrigation.

Flooding method. The close spacing of drilled rows precludes furrow irrigation, and so water is spread from field ditches at various points. The ditches are made immediately after seeding, and the location for them is surveyed beforehand, because they must follow the high spots on the field. This may cut the field in various shapes as the ditches twist and turn from elevation to elevation. Irrigation usually begins at the head of each lateral ditch and works towards its end, since most ditches are made on the down grade. Whenever a ditch has a fill on it, in order to irrigate a higher elevation in the field the water is taken

to that point first. Otherwise the lower elevations along the ditch are watered first and much time is wasted in building up the fills to the level needed to cover the high spots. Also, if the low areas are watered first the peas may be irrigated a second time from the runoff of the higher land. Over-irrigation of peas is harmful.

Soil and irrigation. Heavy soils absorb and give up water slowly, and so must be irrigated for a relatively long period, e.g., ½–1 hour at each application. Also, they take up moisture more rapidly if they are moist than if they have become so dry that they crack or form small crevices. Whenever the soils dry out so much that cracking occurs the plants may be checked in growth and the yield decreased even if water is applied later. Sandy loams take up water rapidly, and, since their water-holding qualities are relatively low, they need more frequent but shorter irrigations. It is wise to maintain the fertility of the soil by avoiding excessive irrigation and to add nutrients from time to time by means of fertilizers, manure, or green-manure crops.

Suitability of the land. Land well suited for irrigation has a gradual slope with a drop of 3–5 inches to 100 feet, and it should be smooth and free of depressions and little knolls. This also encourages the crop to mature evenly for canning. It may be necessary to use levelers and graders to remove high spots and fill low ones. The leveler is used thereafter only in spring just before seeding to fill dead furrows and to remove ridges left by the plow or other implements.

Harvesting

Peas must be picked at the proper stage of maturity and used promptly, because they lose quality rapidly after edible maturity is reached.

Home and market gardens. Many persons do not fully appreciate the need for careful hand picking. Improper picking often consists of jerking the pods from the vines, which injures the plants and reduces later yields. Two, and not infrequently three, pickings of a given variety are needed in order to obtain highest yield and quality.

Harvesting for canning. Uniformity of maturity is a main factor in the production of a quality pack. Pea harvesting

starts 6–8 weeks after seeding, or about 21 days after the plants in a field are in bloom.

The *heat unit* theory is based on the fact that various crops have base on threshold temperatures, below which growth does not occur. Above the base temperature the same plants grow at increasing rates. For peas, the base temperature is 40°F. Heat units are usually computed in "degree days"; some workers use "degree hours," i.e., the degree days multiplied by 24. Information on the number of heat units needed to bring peas to canning maturity is an aid to canners in the scheduling of seeding, in anticipating the peak in the harvest period, and in forecasting harvest of individual fields and viner capacity.

In computing heat units, 40 is subtracted from the mean daily temperature, which gives the heat units in degree days. The mean daily temperature is derived by averaging the maximum and minimum. Thus, for example, if on a certain day the maximum is 63°F. and the minimum is 45°F. the heat units for that day are 63 plus 45 which equals 108, divided by 2 which gives 54, minus 40 which indicates 14 heat units. This value is added to the previously accumulated total, starting at zero on the day of planting. If the daily mean is not above 40°F. no heat units are accumulated on that day. Likewise higher temperatures are given more weight; e.g., a maximum of 90°F. and a minimum of 70°F. works out to 40 heat units. On a day when the mean is 60°F., only 20 heat units are accumulated or half as much as when the mean is 80°F.

In order to anticipate the harvest date of a given variety of peas, it is necessary to know how many heat units must be accumulated to obtain a given quality or maturity level as measured by the tenderometer. Many examples covering several crop seasons were gathered from numerous canners, and the values tabulated were computed.[301]

Variety	*Tenderometer Reading* 100–110
Alaska	1200–1250 heat units
Alsweet and Surprise	1250–1300
Early Sweet and Early Harvest	1300–1350
Pride	1500–1550
Bonneville	1560–1610
Early Perfection	1625–1675
Perfection	1700–1750

The varietal values mentioned cannot be accepted by a canner as the value that will occur in his particular fields. Each canner must develop the values for his own area and varieties. Factors influencing the heat unit accumulation in different fields are: fertility level, soil type, slope, drainage, depth of sowing, stand, vigor of seed, and drought.

Harvesting for canning is done close to the ground with a mowing machine fitted with special guards on the cutter bar, including, in some attachments, a device for rolling the vines back or into windrows to avoid damage when the next swath is cut. In large fields, the peas may be loaded directly from the windrows by a green-forage loader. Dump trucks, particularly those with the hoist at the front end of the platform, save much hand labor in unloading the peas at the viner. If an ordinary mowing machine is used, the cut vines are bunched by hand with forks.

Cutting is best done in the cool of the morning. The cut plants are hauled to the viner which separates the peas from the vines and shells them. Vines cut and left in the field will wilt; if bunched and left for any length of time, they will heat. If a load is brought to the viner too late in the evening for immediate processing, the vines should be unloaded and spread thinly to avoid heating. Portable viners eliminate the necessity of long hauls in the field. For best quality, the shelled peas should be taken promptly to the canning plant and should be put into cans the same day they are harvested.

The common viner will thresh the crop from an acre in 2–4 hours. Where canners estimate their viner capacity beyond these figures they may be unable to handle the peas properly if the weather becomes hot or if the vines make heavy growth or if any abnormal adverse factors occur which the pea grower and canner often encounter.

Some processors pay a flat rate per bushel or per 100 pounds of shelled peas. The processor insists on young peas, but the grower likes to delay delivery to obtain an increase in growth and weight; there is no extra return for a quality crop. A second plan is to pay graduated prices, gaged by inspection of each load of peas; such ratings depend upon the judgment of the inspector. A third plan is to pay one of several prices based

on percentage of peas of a certain size and quality; i.e., small size is associated with immaturity and tenderness. This plan pays according to the one grade of size and quality that may be assigned from a test of the load. In a fourth plan, payment is made on the percentage basis of each factory size or combination of sizes, the smallest peas receiving the highest premium. A fifth plan considers the effect of gravity on a sample of shelled peas in a series of brine solutions. This test separates the peas on a basis of quality rather than size, but it is time-consuming. A sixth plan is a shearing or crushing test with the tenderometer or the texturemeter.

In Utah,[305] Early Perfection showed no correlation between size and quality; i.e., the percentage of starch in sieve grades 1 and 2, as well as 3, increased within the grade as the peas advanced in maturity. Hence, peas harvested at the end of the season in these grades were of poorer quality than those harvested during the first part. But where tenderometer values were compared with the percentage of starch for the ungraded peas as well as with sieve grades 1, 2, and 3, there was a high correlation. That is, as the maturity advanced, both tenderometer value and starch content increased in all sieve grades.

Size Grades

Size grades of canned peas and frozen peas are:

Size	*Pass through Screen, Inch Mesh*	*Retained on Screen, Inch Mesh*
No. 1	9/32	—
No. 2	10/32	9/32
No. 3	11/32	10/32
No. 4	12/32	11/32
No. 5	13/32	12/32
No. 6	14/32	13/32
No. 7	—	14/32

Yield

Yields of fresh market peas vary greatly. About 125 bushels per acre is a fair average. Peas grown for canning usually yield 1,200–3,000 pounds of shelled peas per acre.

Cost of Canning-Pea Production

In Utah,[278] the man labor needed to produce an acre of peas and deliver the crop to the viner shed was 25.9 hours. Of this, 48 percent was in harvesting the crop. Quality of peas delivered was an important factor in the success of the enterprise. Net returns per acre increased as the size of the enterprise increased from 2.0 to 10.8 acres, owing to increased yields combined with decreased labor. As yields increased from 1 ton per acre to 2.4 tons, net returns per acre increased greatly.

Factors Affecting Quality

Sugar-Starch Ratio

In young peas the sugar content increases; then a sharp decrease occurs coincident with an increase in higher carbohydrates, and this continues almost until the peas dry out. The lower carbohydrates, like sugars, are changed into starch and other higher carbohydrates. High sugar and low starch content make for high quality. Warmth hastens the ripening of peas. Growth and ripening are characterized by a rapid decrease in amount of sugar and soluble nitrogenous substances and an increase of starch, total acid hydrolyzable substances, and proteins. These changes are so rapid that a slightly delayed harvest results in much lower quality.

Peas that are late because of late sowing are not always starchier nor lower in sugar than early-maturing peas harvested at the same stage of development; i.e., there is little difference in quality or chemical composition under different temperatures if the crop is harvested at the proper stage. But peas harvested late are quite different from peas of the same size harvested at the right time. Late sowing is associated with more rapid development and maturity and often results in peas passing beyond the proper stage before harvest is completed, and so a lower quality is often found in a late crop.

Calcium-Phosphorus Ratio

Changes in peas as they mature include increases in dry matter and starch, and the migration of calcium to the seed coat, all of which tend to make peas tougher. Calcium and phos-

phorus in the whole pea increase with maturity when calculated on the wet basis, but remain fairly constant on the oven-dry basis. The calcium-phosphorus ratio of the mature pea skins is much higher than that in the skins of either the young raw peas or the canned product. The calcium content and the calcium-phosphorus ratio increase and the phosphorus content decreases with maturity.

Respiration

When shelled peas are stored in large containers before canning there is an increase in temperature in the container, especially in the center, owing to respiration. In shelled green peas at room temperature the sugar content decreases markedly, especially during the first 6 hours, owing to respiration. Bruising peas increases the rate of respiration, and so machine-shelled peas deteriorate faster than hand-shelled peas. The danger indicated by these facts lies in the often unavoidably long periods between harvesting and shelling and the beginning of canning. Peas are given a short heat treatment (blanching) immediately after shelling to inactivate the respiratory enzyme system and thus avoid losses in sugar.

Storage

Fresh unshelled peas of good quality should keep for 2 weeks at 32°F. and 90–95 percent relative humidity. The storage period is about 3 weeks if they are packed in crushed ice. Peas in storage freeze at 30°F.

Insect and Disease Control

The *pea aphid* is a green, long-legged, soft-bodied insect that appears in clusters on terminals, flower buds, and pods. The insects suck sap, cause distortion of the terminals and pods, and reduce yield and quality. Control is spraying or dusting with rotenone or rotenone-nicotine.

Weevil eggs are laid on the pods, and the young larvae bore into the seeds where they complete their development. Dusting with rotenone after blossoming begins and before the first tiny pods appear is a control. Stored seeds are pulverized inside or hollowed out, leaving only the outer skin. A round hole eaten

to the inner surface of the skin is characteristic. Vines and scattered pods should be gathered and burned soon after harvest. (See Fumigation.)

Seed-corn maggot bores into sprouting seed and prevents development of the plant. Controls are: prompt reseeding; avoiding partially decayed organic matter that attracts the flies; shallow seeding and other practices that promote rapid germination.

Seed decay is most common in cool moist weather. Seed treatment (see Table 5, Chapter 15) is helpful.

Ascochyta leaf and pod spot appear as definite sunken tan to brown spots, circular on leaves and pods and elongate on stems. A dark-brown to purple margin usually surrounds the tan spot. In *Ascochyta blight* there are: brown to purple irregular areas on the foliage; black to purple streaks on the stems, pronounced at the nodes; small purple dots on the pods. In *Ascochyta foot rot* the color is black to purple. All three are seed borne; control is seed treatment (see Table 5), clean seed, and eliminating refuse after harvest.

Bacterial blight causes watersoaked spots on the stems, leaves, and stipules. A white to cream-colored slimy ooze appears on the surface of the lesions. The infected area eventually turns brown and papery. If infection gets through the pod to the seed, watersoaked or brown spots occur there. If infection starts from the seed or when the plants are about 3 inches high, the vine may be killed. Later infections reduce the yield. Humid conditions favor the disease; it may dry up under more arid conditions. It is seed borne. Disease-free, western seed should be used.

Septoria blight shows as yellow areas at the edge of the leaf and enlarges until the entire leaf is invaded. Small fruiting bodies occur in the center of the lesion. Seed treatment is a control.

Powdery mildew appears as a dust-like coating on the leaves. The leaves eventually turn yellow. Severe infection results in small brown spots and streaks on the stems together with dwarfing and malformation. It is seed borne. Control is dusting with sulfur, crop rotation, and plowing under diseased tissue.

Fusarium wilt causes a yellowing and downward curling of leaves. The pods are not filled properly; no pods may form. Infection takes place through the roots and follows the vascular

system up the stem, thus hindering the passage of nutrients. If the lower part of the stem or the main root is cut open, there is a lemon discoloration in the canals. Some varieties, e.g., Alaska, are resistant.

Near-wilt may occur on varieties resistant to wilt and attacks the plant later in growth, sometimes near maturity. Near-wilt plants may not show any signs of root decay, but if the taproot is cut open the central core is brick red. If wilt-resistant strains fail to yield well, it may be because of the presence of the near-wilt parasite or even root-rot organisms.

Root rot organisms live indefinitely in the soil and refuse. Controls are crop rotation, drainage, and fertilizer soil.

BEANS

There are a number of different types of beans. These vary greatly in flavor, season, and other characteristics, thus permitting catering to many tastes and purposes.

DWARF BUSH OR SNAP GARDEN BEAN

The pods of the dwarf bush garden bean are cooked when young or at the stage of maturity when they can rightly be called snap beans.

History

Some named snap beans are too old to be traced with certainty, e.g., Red Valentine, Refugee, and Golden Wax. Challenge Black Wax, Davis White Wax, and Bountiful were known before 1900.

Elimination of strings was the chief objective of the early breeders of snap beans, and the most successful among them was N. B. Keeney and C. N. Keeney, LeRoy, N. Y., who produced (between 1890 and 1908) many popular varieties, e.g., Burpee Stringless Green Pod, Giant Stringless Green Pod, one strain of Stringless Green Refugee, Brittle Wax, and Pencil Pod Wax.

The following varieties appeared between 1900 and 1925: Hodson Wax, Full Measure, Webber Wax, and Tendergreen. Since then, many important introductions have been included in the All-America selections, as follows: 1933, Asgrow Stringless Black Valentine; 1935, Asgrow Stringless Green Pod; 1939, Plentiful,

Granda; 1941, Tenderpod; 1942, Medal Refugee; 1944, Keystonian; 1945, Florida Belle, Improved Commodore; 1946, Long Green; 1947, Ranger; 1948, Puregold, Cherokee, Supergreen; 1949, Wax Podded White Seeded, Topcrop. Some other noteworthy varieties include: 1944, Logan; 1947, Rival; 1948, Tiny Green; 1949, Fullgreen; 1950, Contender or Buff Valentine; 1951, Idagreen, Slendergreen, Tenderlong 15.

Classification and Varieties of Snap Beans

A. Green-podded.
- 1. Pod flat to oval.
  - (*a*) Flower white. Not disease tolerant.
    - (i) Mature seed white: Streamliner (Granda, White Seeded Bountiful), Tiny Green.
    - (ii) Mature seed colored: Tennessee Green Pod.
  - (*b*) Flower and mature seed colored.
    - (i) Disease tolerant: Florida Belle.
    - (ii) Not disease tolerant: Black Valentine, Asgrow Black Valentine (Stringless Black Valentine), Bountiful, Prince, Citation (Early Valentine), Plentiful.
- 2. Pod round.
  - (*a*) Flower white.
    - (i) Mature seed white. Disease tolerant: Ranger.
    - (ii) Mature seed colored. Not disease tolerant: Stringless Red Valentine.
  - (*b*) Flower and mature seed colored.
    - (i) Disease tolerant: Contender (Buff Valentine), Dixie Belle, Flight, Improved Full Measure, Idagreen, Logan, Refugee U. S. 5, Idaho Refugee, Rival, Sensation Refugee 1066 and 1071, Tenderlong 15, Topcrop, Wade.
    - (ii) Not disease tolerant: Asgrow Stringless Green Pod (Tendergreen), Improved Commodore, Full Measure, Giant Stringless Green Pod, Keystonian, Longfellow, Long Green (Long Tendergreen), Refugee 1000–1, Stringless Green Refugee, Tenderlong, Tenderpod.
  - (*c*) Flower colored. Mature seed white. Disease tolerant: Emerson 15.

B. Wax or yellow-podded.
- 1. Pod flat or oval.
  - (*a*) Flower white. Not disease tolerant.
    - (i) Mature seed white: Davis White Wax, Pacer, Strider, Wardwell Kidney Wax.
    - (ii) Mature seed colored: Improved Golden Wax, Topnotch Golden Wax, Webber Wax.

(*b*) Flower and mature seed colored.
  (i) Disease tolerant: Cherokee, Currie Rustproof.
  (ii) Not disease tolerant: Stringless Kidney Wax Improved, Surecrop Wax (Bountiful Wax), Unrivalled Wax.

2. Pod round.
  (*a*) Flower and mature seed white. Not disease tolerant: Brittle Wax White Seed (Kinghorn Special).
  (*b*) Flower white. Mature seed colored.
    (i) Disease tolerant: Brittle Wax Improved, Puregold.
    (ii) Not disease tolerant: Brittle Wax (Round Pod Kidney Wax), Sensation Wax No. 1.
  (*c*) Flower and mature seed colored. Not disease tolerant: Challenge Black Wax, Pencil Pod Black Wax, Prolific Black Wax, Refugee Wax.

Asgrow Black Valentine and *Plentiful* are leading green-podded varieties in the South. *Florida Belle* is more disease tolerant. In many regions, old stand-bys are *Bountiful, Stringless Greenpod, Refugee,* and *Tendergreen.* Improvements on these in various respects are *Contender, Fullgreen, Logan, Ranger, Rival, Tenderlong 15* and *Topcrop.*

Wax beans are grown extensively in the South for shipping, e.g., *Hodson Wax. Cherokee* is fairly popular. *Davis White Wax* is widely grown owing to its earliness, appearance, pods, heavy yield, and good shipping qualities.

In the round-wax-podded type, *Brittle Wax Improved* is a first choice for home garden and market. *Round Pod Kidney Wax* is an old favorite. *Puregold* is a good processing variety.

Producing Bush Snap Beans

Climate

Except for broad beans, all beans are warm-season plants. The snap bean is sensitive both to frost and to very high temperature. The seed will not germinate in cold soil. Beans will succeed with less moisture than many other crops, but they need a fair amount. The plants may drop their blossoms or pods in very hot or rainy weather. Cool weather may make round-podded varieties flatter. Cold, cutting winds may cause much damage. Since snap beans are used while immature, they need only a relatively short season.

Soil and Fertilizer

Seedling emergence. Beans (except the runner type) differ from many other kinds of plants in that on germination they send up two seed halves or cotyledons which are large and seriously hampered in movement by compact or crusted soil. Beans thrive well on silt, clay loams, and heavy soils that are so prepared that they will not hinder the free movement of the young

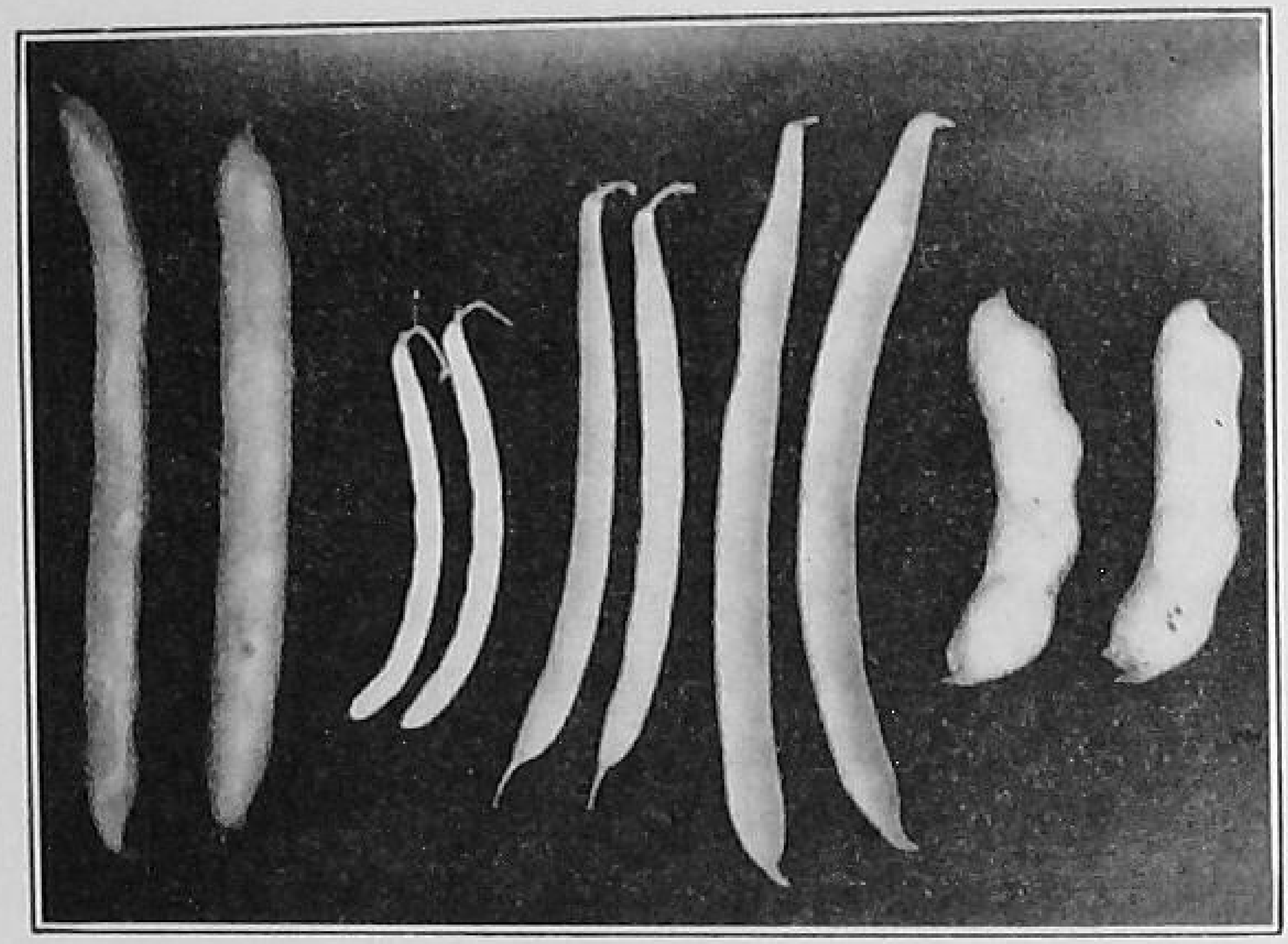

Fig. 23. Beans. *Left to right:* Longpod; dwarf bush wax; dwarf bush green-podded; pole; Windsor broad.

seedling in emergence. Beans in a rotation should follow a cultivated crop with a more vigorous root system. For canning crops especially, the land should be such as to give uniform maturity.

In areas of heavy rainfall beans are sown on raised beds for good drainage. In row-irrigation areas, the necessary construction of water furrows causes some ridging of the soil at the base of the plants. In moderate-rainfall areas and in overhead-irrigation areas, raised beds or ridges are rarely used. In semi-arid areas, listing, the opposite of ridging, may be necessary.

Soil reaction. The optimum *p*H may be 5.8–6.0. But in southern Alberta irrigated soils with a *p*H of 7.8–8.0 produce excellent bean crops.

Fertilizer needs. Bush beans yield best on a fairly fertile soil, but a very rich soil may result in too much vine growth at

the expense of pod yield. The bean is a relatively light feeder; moderate amounts of manure should be applied. Yields are often increased by nitrogen fertilizer when there is a low population of nitrogen-fixing bacteria in the soil. Beans often respond well to a fertilizer that is high in phosphorus. Potash is also often helpful.

Applying fertilizer. Beans are easily injured by fertilizer in direct contact with the seed. Plants that are stunted by fertilizer when young rarely recover their vigor fully. Some of the fertilizer may be broadcast at, or preferably 2 weeks before, seeding, and the rest applied as a sidedressing later. One plan is to place a band of fertilizer on each side, 2–3 inches from the row and 1½ inches deep. To avoid burning of the young plants, close off the fertilizer tubes through which the seed is sown and sow the fertilizer only through the remaining tubes.

Nitrogen starvation in beans sometimes can be corrected[392] by sidedressing with nitrogen fertilizer provided it is done at least 3 weeks before picking and adequate rainfall then occurs to move the nitrogen down to the roots.

Time of Seeding

A safe procedure is to sow about at the time of, or slightly earlier than, the average frost-free period for a given district. Growers of snap beans for early use or market often take chances with late spring frosts; if the plants are damaged reseeding is done.

In the South seeding is timed so that the nonhardy varieties will not be caught by either too hot or too cold weather at podding time. In Louisiana,[83] for example, the spring planting season is late February and early March. In the spring, earliness is important, because early beans that escape injury from cold become ready when the price is usually the best and generally make heavier yields. In the fall, planting is done from August 10 to September 15. If the fall crop is planted too early, it is likely to be severely injured by hot weather and insects; also, the beans may mature too early for the northern market.

To maintain a continuous supply of snap beans, simultaneous sowing of several varieties of different times of maturity, or of different types, is likely to give better results than sowing one

variety at intervals, though both methods may be used. Late sowings often fail to make progress owing to drought.

Spacing and Rate of Seeding

Seeding singly in rows 1½–3 feet apart is usual with bush snap beans. Seed is dropped 2–3 inches apart in each row. In Pennsylvania,[294] the maximum yield in 3-foot rows is produced when the spacing in the row is 1–2½ inches. About 75 pounds of seed are needed to sow an acre at 2-inch spacing in 3-foot rows, assuming nearly perfect germination. At 1-inch spacing twice this amount of seed is needed, and lesser amounts at wider spacing. Taking the price of seed into consideration, the 3-inch spacing is probably the most practical rate of seeding, since the yield at this spacing is not greatly reduced as compared with the yield at the closer spacings.

Southern growers sow more snap bean seed than do growers in other regions. For canning in Wisconsin and for canning and market-garden purposes in Colorado 20–30 pounds are sown per acre, but in Florida sowing market-garden beans at 60–120 pounds per acre is general. In South Carolina, 60–75 pounds per acre are sown. Bean seed soon loses its vitality if it is stored under hot, humid conditions. Many southern growers can reduce the rate of sowing by getting seed as needed or by having it held in suitable storage. Heavy rain within 24 hours after seeding usually reduces the stand to some extent, and so an increased rate of seeding may be wise if such weather is anticipated. With good germination, high rates of seeding may actually reduce the yield per acre, and they always reduce the yield per plant.

In large plantings a 2-row corn planter with special bean plates, a bean planter, or a grain drill on which all the drill holes are stopped except those spaced at the proper distance for dropping the beans may be used for seeding. An old method with bush snap beans is to make a flat-bottomed furrow and place the seeds 4–6 inches apart in stagger fashion. The plants then support each other better.

Depth of Seeding

Bean seed is usually sown just deep enough to get it into moist soil. It should not be covered by more than 1 inch in heavy

soils and 1½ inches in sandy soils; 1½ inches is a good average. On light Coastal Plain soils in South Carolina increased depth up to 2 inches gives somewhat better stands than ½ inch, but dry-root-rot infection increases with depth of seeding. To obtain adequate moisture, furrows may need to be made 4–6 inches deep but the seed covered only 1–2 inches, depending upon soil type and temperature.

Tillage

Injury in cultivation reduces the yield; root injury may cause the blossoms to drop. Most of the root system is in the top 6–8 inches of the soil and much of it in the top 2 inches. When the plants are nearly full size, cultivation may do more harm than good. Anthracnose and bacterial blight are seriously spread if the plants are cultivated while wet. In the South, cultivation is followed with a sweep 14–18 inches wide to move soil close to the base of the plants and to help maintain the fairly high beds which may undergo washing down by rains.

Irrigation

Beans seldom need to be irrigated before they germinate, because the seeds are large enough so that they can be placed in contact with the soil moisture. But if the soil has dried out through spring plowing, it is wise to irrigate first and then sow, because irrigation may wash out the seed. Small furrows, made by shoving the loose top soil to the sides and up against the plants, keep the water from touching the plants and also help to guide it over uneven land. Long rows are desirable, but if they are quite long and the water must run for a considerable time so as to soak the far end, the top end of the row may receive too much water. To prevent this, the stream is run halfway down the rows long enough to soak the soil and then it is run in a ditch at the side and halfway down the length of the field. Water is then directed into the rows for the bottom half of the field.

A good supply of moisture is essential while the plants are young. It is also necessary to maintain a uniform supply of soil moisture as the plants begin to bloom. The blossoms may fail to set or may drop if the soil becomes either too dry or

too wet. Less frequent irrigation is needed on a heavy soil than on a sandy soil.

It may be wise to irrigate after each picking if the field is picked once or twice a week. But these irrigations are generally a rapid flush-over instead of a soaking. They encourage the plants to recuperate rapidly, especially if the pickers have been rough, speed up the growth of immature pods, and promote tender pods.

Harvesting

A common yield is 85 bushels per acre (30 pound per bushel). Practically all snap beans are shipped in 1-bushel hampers or 1-bushel tub baskets, although market gardeners use other containers, including the 16- and 24-quart splint baskets.

Pods are usually ready for harvest within 2–3 weeks of the first bloom. Early kinds like Stringless Black Valentine and Brittle Wax become marketable in 50–55 days after seeding, whereas Stringless Green Refugee is about 2 weeks later.

Snap beans are usually picked before the pods reach full size and while the seeds are beginning to swell. When the seeds are so large that definite restrictions occur in the pods, the best edible stage has passed, and the pods are tough and stringy. When harvested, the pod surfaces should be dry, since they are apt to heat and mold if they are kept in a container when moist. Packages of beans for the market should be well filled by being shaken while they are packed.

The canning crop, if it is to be harvested at one picking, may, in some cases, be handled with the mechanical bean picker. This machine is mounted on a light farm tractor and consists of rotating drums equipped with rubber fingers which rake the beans and leaves from the plants as it passes over them. The beans are caught on a conveyor belt, pass over an air blast to remove the leaves, and are delivered to bags carried at the rear of the machine.

Storage

Snap beans can be stored only for short periods. They keep better at 40°F. than at 32°F. or 50°F. The humidity preferably should be above 90 percent to prevent wilting, and there should

be good air circulation. If beans are stored too long, the pods become moldy or slimy. They should be free from surface moisture when stored and should be kept from contact with ice.

The chief after-harvest changes in snap beans involve carbohydrates, e.g., hydrolysis of starch and an accumulation of total sugars; low temperatures accelerate the latter. During storage snap beans lose crispness, owing to a loss of water and possibly also to an increase in soluble pectin. Starch decreases and sugars increase in the pods; the reverse occurs in the seeds. There is little, if any, translocation of sugars from pods to seeds during storage. Hemicellulose is more abundant in the pods and after harvest increases in the seeds and decreases in the pods.

Commercial Canning

Snap beans are canned in two ways. They are either processed after the pods are cut into ½-inch pieces or they are canned whole with only the tips and ends removed. Straight pods are preferable, otherwise there is much loss; i.e., if curved pods are packed whole they do not fit into the cans well, and if they go through the bean-cutter machine, small and slant-cut pieces at the ends of the pods unsuitable for canning are produced and must be discarded.

POLE GARDEN BEAN

The distinction between the pole and bush types is due to a single pair of characteristics: the indeterminate growth habit (axillary inflorescence, and so the stems may elongate indefinitely) of the pole bean is dominant over the determinate habit (main axis terminates in a flower cluster, thus preventing stem elongation) of the bush bean.

Beans that climb do so by virtue of their sinuous, twining stems. The absence of tendrils or tendril leaves in beans is one feature which distinguishes them from peas. The ability to climb is a constant character but does not allow separation into this class until the plants are well along in growth. Pole beans are usually later than bush beans but bear for a longer period, and some produce larger pods. This type is chiefly grown commercially in a few canning areas in the West where the extra cost of handling is offset by the yield and price.

A. Green-podded.

1. Pods flat to oval.
   - (*a*) Mature seed white.
     - (i) Disease tolerant: Coaster.
     - (ii) Not disease tolerant: Lazy Wife (White Cranberry, White Cherry), McCaslan.
   - (*b*) Mature seed colored. Not disease tolerant: Delicious Giant, Dutch Caseknife, Green Savage, Nobility, Oregon Giant.
2. Pods round to crease-backed.
   - (*a*) Mature seed white.
     - (i) Disease tolerant: Blue Lake 65, Stringless Blue Lake B-5, Blue Lake Stringless, Decatur, Rialto, White Seed Kentucky Wonder 191.
     - (ii) Not disease tolerant: Blue Lake (White Creaseback Improved), Burger's Green Pod Stringless (White Seeded Kentucky Wonder), Early Blue Lake, St. Louis Perfection (White Cornfield Improved), White Creaseback (Fathorse).
   - (*b*) Mature seed colored.
     - (i) Disease tolerant: Black Seeded Blue Lake (Stringless Black Creaseback, Potomac, Ideal Market Stringless), Rust Resistant Kentucky Wonder.
     - (ii) Not disease tolerant: Black Creaseback (Black Cornfield, Black Valentine Pole), Canfreezer, Improved Missouri Wonder, Kentucky Wonder (Old Homestead, Texas Prolific), Stringless Kentucky Wonder, Scotia (Striped Creaseback, Nancy Davis), Long Type Tennessee Wonder.

B. Yellow-podded: Golden Cluster Wax, Kentucky Wonder Wax.

C. Purple-podded: Victor.

The large acreage in the West is based on the "Cornfield" type. Instead of possessing large, pole bean pods, this type has slender, pencil-like pods which are excellent for processing. The name "Cornfield" is derived from the fact that in the South this type is often sown in corn fields. *Blue Lake,* and its strains, is a leader in the West.

Pole beans need a richer soil than bush snap beans. When pole beans are sown singly in rows the seeds usually are placed 4–6 inches apart. When a wire trellis or fence is used for support the spacing is often a foot between plants. Seeding in hills * is common with pole beans. The hills are spaced 3–4 × 3–4 feet

* The garden term "hill" traces back, in part, to pioneer days when, eager to start planting before ground could be broken, settlers turned over a piece of sod and scattered seeds on top of it. The planting was raised and therefore a hill. Nowadays, a hill commonly means an area 6–10 inches in diameter sown with 4–6 seeds.

apart, 4–6 seeds are dropped in each space, and these are later thinned to 2–4 plants per hill.

Pole and runner beans need support. They climb counterclockwise. Small saplings 5–9 feet long and 2 inches thick at the base may be set firmly in the ground at, or before, seeding, 3–4 feet apart each way. Bark and stubs of small branches left on the poles aid the beans in climbing. With sawed stakes, the corners and smoothness make the climbing difficult. Sometimes 3 poles are placed in teepee-like form 3 feet apart each way, and each group of 3 tied at the top, 4–6 seeds being sown near the foot of each pole.

Pole beans may also be trained on a trellis, as in western Washington.[58] *Posts or poles:* 3 × 3 inch 9-foot poles are set 1½ feet in the ground and spaced 10 feet apart in the row; 1 × 1 inch pea stakes may replace every other pole. The end posts are braced with a wire and stake. *Wire or string:* No. 9 gage wire is used for the top wire and No. 16 wire or pea twine for the bottom of the trellis.

In the *hoop system,* the string (No. 4 ply cotton twine) is tied to the top wire, passed under the bottom wire or string and around it once, and back over the top wire and around it. This procedure is continued the full length of the row. The string is spaced 12 inches along the wire. It is wise to take at least one half-hitch between poles to prevent the entire row from going down in the event that the string should break.

In the *half-hitch system* no bottom wire or string is used. The twine is tied to the top wire, dropped vertically to the hill, half-hitched around the plants in the hill, and brought over to the next hill where a half-hitch is made around the plants in this hill. The string is then brought up vertically to the top wire, double half-hitched, and carried along the top wire to a position above the next hill, where it is again half-hitched and dropped vertically to the hill below. The process is repeated along the length of the row.

It is necessary to train the runners on the strings when the plants are 4–5 inches tall. Vines growing beyond the top trellis wire are trained along the wire.

Pole beans bear over a longer period of time than bush snap beans. They develop in succession from the first clusters upwards. Care in harvesting when the pods are ready gives pro-

gressive crops of highest quality. In the Pacific Northwest, the chief production area, pole beans sometimes yield as high as 10 tons per acre.

LIMA BEAN

The botanical differences between lima and common beans are not great, but the two types are not cross-compatible. The presence of the glucoside linamarin, the result of two enzymes which impart the characteristic lima bean flavor, is found in no other bean.[242] The flower bracts are small, inconspicuous, lanceolate, and pointed in limas, and large, conspicuous, and oval in common beans. Lima beans are used as shell beans.

History

The lima bean originated in or near Guatemala. Distribution from the original source of the wild progenitor indicates three lines: [242] (*a*) a Hopi branch, extending northward in the United States; (*b*) a Carib branch, carried to islands in the West Indies and to the Amazon basin; and (*c*) an Inca branch, which traveled south from the Central American point of origin to Peru. These lines of dispersal followed the trade routes of the Indians in pre-Columbian times.

Classification and Varieties

A. Pole.
- 1. Large-seeded; cotyledons white.
  - (*a*) White seed coat: King of the Garden, Large White (Giant Podded, Carpenteria, Leviathan), Ideal (Mammoth Podded).
  - (*b*) Green seed coat: Challenge (Fordhook Pole, Burpee Best), Seilbert's Early.
  - (*c*) Speckled seed coat: Giant Butter (Christmas), Large Speckled.
- 2. Medium-seeded; cotyledons white; green seed coat: Early Jersey.
- 3. Small to very small-seeded; cotyledons white.
  - (*a*) White seed coat: Sieva (Small White Carolina), White Pole Butterpea, Willow Leaf, Wood's Improved.
  - (*b*) Red seed coat: Red Pole Butterpea.
  - (*c*) Speckled seed coat: Florida Butter.

B. Semi-pole or intermediate. Small seed; white cotyledons; white seed coat: Hopi, Weston, Wilbur.

C. Dwarf or bush.
- 1. Large-seeded; cotyledons white.
  - (*a*) White seed coat: Burpee Bush, White Mountain, Ventura.

(*b*) Tinged green seed coat: Fordhook (Potato Lima), Fordhook 242, Concentrated Fordhook, Burpee Improved Bush, Early Market.

2. Medium-seeded; cotyledons white; light to medium-green seed coat: Peerless, U. S. 345.
3. Small-seeded.
   (*a*) Cotyledons white: Baby Potato, Bixby, Early Baby Potato, Maryland Thick Seeded, Henderson Bush (Baby Lima, Dwarf Carolina, Dwarf Sieva, Earliest Bush, Landreth Bush, Prolific Bush, Small White Bush), Wood's Prolific, Triumph, Cowey Red, Jackson Wonder Speckled (Calico).
   (*b*) Cotyledons green: Allgreen, Evergreen, Thorogreen, Cangreen, Clark's Bush, Early Thorogreen, Emerald Green.
4. Very small-seeded; cotyledons white; seed coat white: Dixie Butterpea.

For many years, *Henderson Bush* has been a leader for freezing and canning. For these purposes, more intense green color in the processed beans is found in *Thorogreen, Clark's Bush,* and *Cangreen. Early Thorogreen* is earlier and has extended successful culture farther north. *Peerless, Triumph,* and *Early Market,* as well as *Fordhook* and *Burpee* types, are popular for market. The semi-pole type is allowed to sprawl on the ground in California when grown commercially. "Potato" varieties are plump, with blunt ends, and crowded in the pod. Bixby (Fordhook × Henderson Bush), a baby lima, introduced by the Oklahoma Agricultural and Mechanical College in 1951, is several days later than Henderson Bush.

Fruiting Habit

The Henderson Bush lima often tends to revert to its ancestral form and twine. If plants are artificially shaded at 23–25 days after the seedlings appear, an elongation of internodes 7 and 8 occurs with a consequent twining of the main axis.[165] This condition does not occur if the shade is delayed even a few days. The shade causes an early maturity of the terminal pods. If the crop is harvested when most seeds are green, those of the terminal raceme will be white and undesirable for canning. A few cloudy or rainy days when the plants are at this critical stage results in an undesirable condition like that from the shade. Thus, seed sown from the same lot on different dates may show twining and irregular maturity in some plants and not in others. But dry weather may make the cotyledons of the seed become white be-

fore they reach normal size.[59] This condition causes a rapid maturity of the pods over the entire plant rather than only on the terminal raceme.

FIG. 24. Fordhook, Asgrow-strain lima bean. A special strain bred for concentration both of maturity and of position of the pod to make for rapidity and efficiency in handling. (*Courtesy Associated Seed Growers, Inc.*)

CLIMATE

Pole limas need a frost-free period of about 4 months with warm days and nights; bush limas produce a crop in a slightly shorter time. When the soil is cool the seed may germinate slowly or rot; hence the growing season of limas cannot be extended by sowing as early as might seem possible, although seed treatment aids success with comparatively early sowing. Also, the first blossoms may be lost, and if the blossoms drop because of drought, very hot weather, or some other cause, there is not time, in short seasons, for later ones to set and develop sufficiently.

SEEDING

In general, seeds of bush limas are planted in rows 2–3 feet apart and covered 1–2 inches deep. Pole varieties require more

space, and the planting distance is determined by the method of staking that is to be used.

In Pennsylvania,[226] a spacing of 30 × 2 inches was generally best for Fordhook 242 and Thorogreen. In Wisconsin,[352] where seeds of Henderson Bush for canning were planted 1, 2, 4, and 8 inches apart, the yield per acre increased as the rate of seeding was increased. Hence, the heavier the seeding rate the better, up to the point where seed costs outweigh the increase in yield.

Fertilizer

Best yields of limas in Delaware[310] were obtained (*a*) where a combination of drilling and banding was practiced—500 pounds of complete fertilizer (4-8-12) drilled before planting and 250 pounds banded at planting (banding 3 inches to each side of the row and 3 inches deep, with a 2-row bean planter), and (*b*) where 5 tons of poultry manure was broadcast before plowing followed by banding of 500 pounds of complete fertilizer at planting.

In Washington State, supplemental nitrogen is needed for limas even though the seeds are inoculated at seeding time. At least 60 pounds of nitrogen per acre are essential on poor soils.

Harvesting

Bush varieties produce beans large enough for use as green beans in 75–90 days from planting, depending upon the variety and location. The harvest period of green beans extends over about 50 days in the South, and for progressively shorter periods northward. Pole varieties come into bearing about 10 days to 2 weeks later and continue to bear over a longer period than bush varieties.

Beans that are to be used green, canned, or as dried-green beans should be harvested after they have reached maximum size but before they have changed from green to white (in varieties that turn white). Plants bear over a longer period and make greater yields if beans are not allowed to mature before harvesting. Dry beans should be harvested at periodic intervals as they mature throughout the season. This is especially necessary with the small-seeded varieties, because the pods open and the beans shatter if not harvested soon after they mature. Large plantings, whether grown for use as green or dry beans, are harvested with bean cutters.

In limas the percentage of seeds that have turned white may be used as an index of canning maturity for those varieties that turn white upon maturation.[218] The tenderometer can be used with both white- and green-seeded varieties, but different scales of values are necessary for different varieties. The "maximum yield stage" is the point at which the largest portion of the beans in the field are at their maximum size. The point can be arrived at only by means of several successive harvestings. For Henderson Bush, this point is reached when about 40 percent of the beans have turned white and the tenderometer reading (equipped to register 400 pounds shearing force) is about 300. For Peerless, the same point is reached when the beans are about 35 percent white and the tenderometer reading is about 210. The time between vining and blanching should be kept to a minimum, since the quality of the vined lima beans deteriorates very rapidly.

Storage

Limas, unshelled, store well for 2–3 weeks at 32°F. Although the pods before the end of this time will become more or less discolored, the seeds will be bright, clean, and of good quality.

Limas shell better if the pods are allowed to wilt slightly after harvest. Green beans that are to be kept for any considerable length of time should be spread out for a short time after they have been shelled so that the surface of the beans may become dry; otherwise they will be injured by mildew.

Fresh limas may develop at least two other serious troubles after being shelled: (*a*) a slimy, sticky, bacterial condition of the surface, so that the beans stick to the fingers when touched; (*b*) a superficial fungous spotting. Washing the beans in 30 percent ethyl alcohol or washing the pods in a 4 percent solution of chlorinated lime gives complete control of spotting and good control of stickiness.

DRY-SHELL BEAN AND HORTICULTURAL BEAN

Shell beans are a type of bush bean developed for the production of seed to be used dry. The pods are harvested when they are quite dry, and then threshed for winter use. The seeds are usually a solid white, red, brown, yellow, or black. In the horticultural or cranberry bean the pods become brilliantly splashed with red.

The term "kidney bean" may trace back to the doctrine of signatures. This is the old idea or theory that marks, color, and so forth, signified uses in medicine. Thus it was supposed that because the seed is shaped like a kidney it must be good for that organ.

The various dry bean types are not in direct competition with each other. People of Mexican descent in southwestern United States prefer pinto beans; the miners of the southeast like the cranberry type; red kidneys find favor in the West Indies and in the canning trade; and yellow eyes are in demand in New England. The white classes are widely marketed throughout this continent. Great Northern and white pea beans compete through the dry bean trade for preparation in the home, but the canning trade wants the pea bean because it retains its shape after proper processing.

Navy is small, white seeded, and much used for cooking and baking. The name refers to the preference of the American Navy for beans of this type for use at sea. Nearly a hundred names have been applied to these beans. Of the white-seeded beans used for cooking or baking, there are the white marrows, the white kidney beans, and a third type made up of the smaller-seeded sorts such as *Great Northern* (including a number of Idaho selections), *Lady Washington, Robust, Navy Pea,* and *Small White.*

Michelite is highly disease resistant, is desirable in other ways, and is considered superior to the older Robust. *Pinto* is much used for chile con carne.

London Horticultural and *Mammoth Horticultural* are pole varieties. *Low's Champion* and *French Horticultural* are dwarf. *Brilliant* (semi-trailing) and *Flash* (dwarf) are recent introductions from New Hampshire.

In Michigan,[312] it is wise to sow white pea and cranberry beans June 1–10. They may be sown in late May but then risk meeting cold weather, slow germination, and more maggot injury. Beans sown in May also tend to set pods both early and late, thereby complicating harvest because of uneven maturity. Red kidney beans are more subject to blight if sown before June 15–20.

Rows of dry shell beans are commonly spaced 28 inches apart. Sowing white pea beans in 28-inch rows at a rate of about 5 seeds per foot takes 40 pounds of seed per acre.

Field or dry-shell beans are harvested when a high percentage of the pods have matured and turned yellow. Most varieties ripen unevenly, and so harvesting begins before the pods get dry enough to shatter.

RUNNER BEAN

The runner bean may grow 12 feet or more tall. It is chiefly esteemed in America as an ornamental climber for porches and fences because of its rapid growth and large, scarlet flowers on long stems, but it is probably the most popular type of bean now grown in England. The snap pods are stringy and fibrous, except when very young or quickly grown. The cotyledons remain below ground when the seed germinates, thus differing from other types of bean. The root is conspicuously thickened.

The runner bean is probably a native of Central or South America. It was taken from there to England in 1633, where it was first grown by John Tradescant of Lambeth. For a century it was valued only as an ornamental plant; then Philip Miller of the Chelsea Gardens brought it forward for table use.

A. *Streamline type.* Seed purple with black markings; flowers scarlet and showy.
  1. Pod 6 inches long, ¾ inch broad: Scarlet Runner.
  2. Pod 10 inches long, 1 inch broad: Best of All.
  3. Pod 12 inches long, 1 inch broad: Streamline.
  4. Pod 15 inches long, 1 inch broad: Goliath.

B. *Prizewinner type.* Seed purple with few black markings; flowers scarlet and especially brilliant and showy; pod 12 inches long, 1 inch broad.

C. *White Dutch type.* Seed and flower white; pod 5 inches long, ½ inch broad.

The large seed is sown about 2 inches deep. For subsequent culture, see under Pole Beans.

BROAD BEAN

The broad bean, which is the bean of history, has been grown from prehistoric times. It is native to northern Africa and southwest Asia, most likely near the Caspian Sea. Seeds found in Swiss lake dwellings have been attributed to the Bronze Age. This bean was known and grown by the Greeks, Romans, Hebrews, Egyptians, and other ancient nations.

Until the goddess Carna was invested Italy's soil produced no vegetable without man's help, excepting beans; hence in her particular feasts the usual offering was beans. In Roman courts or in public bodies where questions were put to vote, the ancient ballot was a bean, a white one representing innocence; a black one, guilt. Such, then, was the importance of the bean that we need feel no surprise that one of the foremost families in Rome, the Fabians, to wit, should have taken the name of it. The Coepiones of that day were merely the Messrs. Onion; the Pisones were the Peas; Cicero was Mr. Chick-pea; the Lentucini were the Lettuce family.[353]

The broad bean resembles a huge pea or lima bean more than an ordinary bean and is used like a green pea. There is a felt-like padding inside the pod between the pod wall and the seed. At maturity the spongy felt surrounding the seed disappears.

A. Longpod. Pods long (5–7 inches), contain 4–7 seeds.
- 1. White-seeded.
  - (*a*) Eye white: Victoria, Threefold White.
  - (*b*) Eye dark: Aquadulce, Champion, Eclipse, Hangdown, Monarch, Seville.
- 2. Green-seeded: Green Leviathan, Olympic, Green Masterpiece.

B. Windsor. Pods short, contain 3–4 seeds.
- 1. White-seeded.
  - (*a*) Eye white: Victory, Early White-eyed.
  - (*b*) Eye dark: Broad Windsor, Taylor Windsor, Harlington Windsor.
- 2. Green-seeded: Green Windsor.

C. Dwarf fan-podded. Very short internodes; small, dark-green foliage; 15 inches tall; short, narrow pods arranged in fan form; seeds small; 2–3 seeds.
- 1. White-seeded: Dwarf White Fan, Early Magazan.
- 2. Cream-seeded: Green Gem.

Broad Windsor and *Hangdown* are leading varieties.

The broad bean is a cool-season crop and is suited only to northern areas on this continent. It does not thrive where summers are hot. It is also very subject to attacks of the black aphis. The broad bean has long been popular in Europe. The seed will germinate in a cooler soil than will snap beans. Broad beans require a longer season but may be sown earlier than snap beans.

The seed of the broad bean is large and is commonly sown about 2 inches deep. The seed is usually placed singly 4–6 inches apart, or in double drills 8–10 inches apart, in rows 2–2½ feet apart. When the plants are well set with fruit it is wise to remove all side growths and to pinch out the growing points. This checks the upward growth and encourages swelling of the pods.

EDIBLE SOYBEAN

The soybean is a native of southeastern Asia. It has been cultivated in Japan, India, and China since ancient times.

Plants of the edible soybean grow 1½–2 feet tall. The pods are hairy and blunt, contain 3–4 seeds, and are picked when well filled but still green. The seeds may be shelled out of the green pods by hand or they may be put through a pea viner. The edible soybean is used, in green form, as a vegetable, in

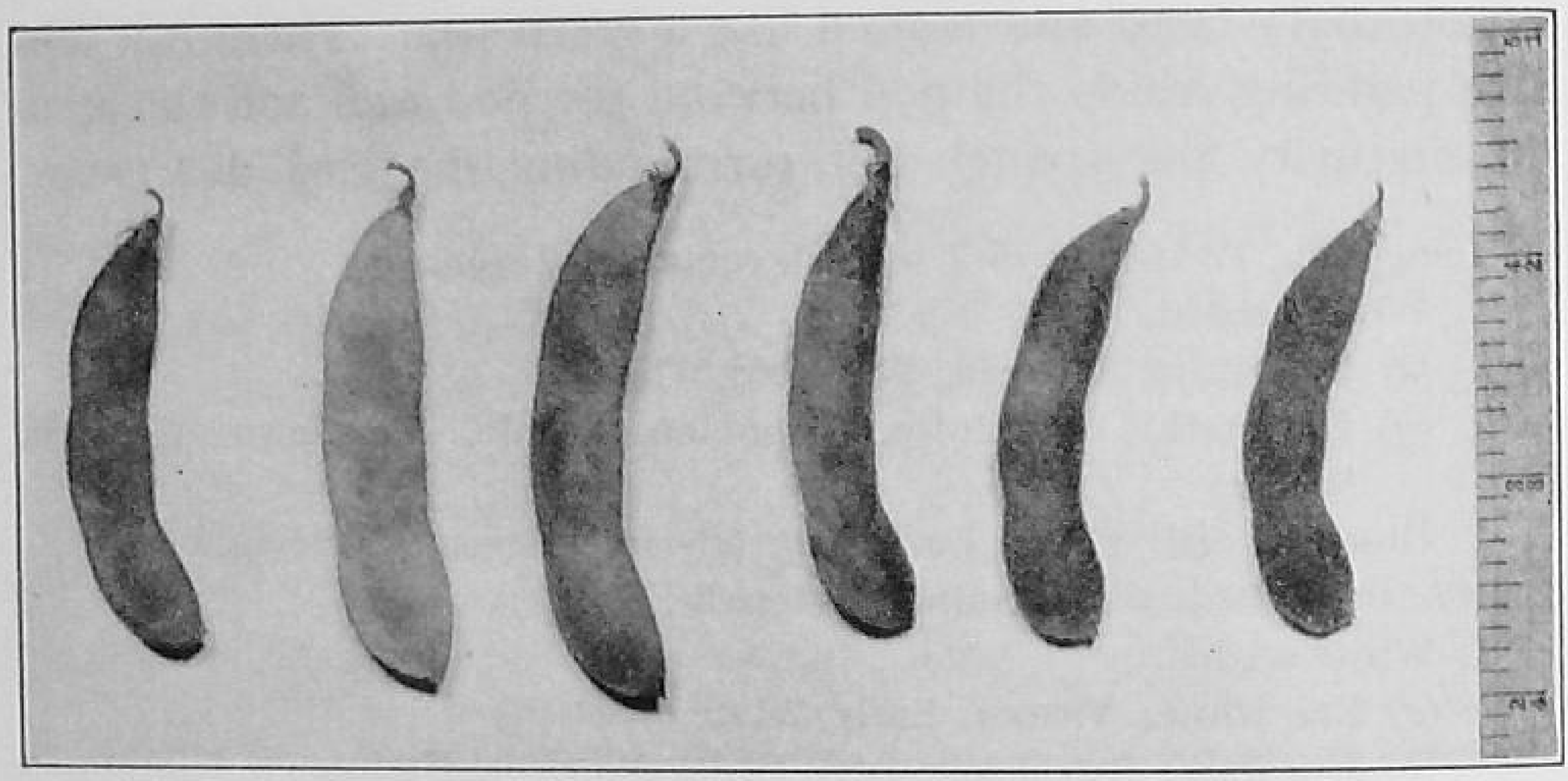

FIG. 25. Six varieties of edible soybean.

salads, and canned and, in dried form, baked, boiled, salted, in sauces, as cooking oil, and in numerous other ways. Dry soybeans are cooked like ordinary dry beans. The soybean is very nutritious.

Popular varieties are *Bansei, Kabott, Giant Green*, and *Agate*.

The soybean has about the same climatic adaptations as corn. The rows are spaced 2½–3 feet apart, and the seed is sown so as to have one plant every 10–15 inches in the row.

Edible soybeans are picked when about full size but while still green, or when the pods are starting to change from green to brown.

Insect and Disease Control

Mexican bean beetle adults are copper colored and have 16 black spots. Yellow eggs are laid on the underside of the leaves. The larvae are fuzzy, yellow, ¼ inch long, and change to pupae that hang from the undersides of the leaves. The leaves are skeletonized. Sections are eaten out of the pods, or pits are made

in their surface. When both beetles and larvae feed on the leaves, the plants may be killed. Control is dusting or spraying with rotenone or methoxychlor, or with parathion until 30 days of harvest.

The *corn earworm* eats holes in the pods. Control is spraying or dusting with methoxychlor or parathion. These materials will also control *leafhoppers* which cause the leaves to be puckered or cupped and the margins to turn yellow and die.

The *red spider mite* causes the leaves to become blotched with yellow and brown spots. Injury occurs chiefly in dry, hot weather. Control is dusting with superfine sulfur at 10-day intervals, or dusting or spraying with parathion.

Bacterial blights show as watersoaked, later brown, spots on leaves, stems, pods, and seeds. In severe cases, the plants are stunted, wilt, and die. A bacterial exudate may form a crust on leaves and stem. Yellowish spots occur on the seeds. In *halo blight* a chlorotic halo surrounds the spots on the leaves. In *bacterial wilt,* stunting and wilting occur but leaf spotting is absent. Blight is seed borne, and so disease-free seed must be sown. Cultivation while the plants are wet must be avoided.

Common bean mosaic badly affected plants are stunted and sickly yellow with the leaves puckered and mottled with alternate light-green and dark-green patches. It usually causes more severe damage on susceptible field beans than on the leading garden beans.

Bacterial spot of lima bean shows as brown to purplish-red lesions (never watersoaked) on the leaves, with streaks on veins and petioles and elongated lesions on the stems or brown spots on the pods surrounded by watersoaked halo. Dusting or spraying with copper substances is helpful.

Anthracnose or *pod spot* is seed borne. It shows as dark, sunken, circular cankers in the pods and blighting of the leaves. Most bean seed is now produced in the West, where the dry climate hinders the development of the disease. Helpful practices are: using disease-free seed, rotating the crops, and staying out of the field when the plants are wet.

Downy mildew causes white, cottony growth that forms in large patches on the pods of lima beans. Seed from an infected crop should be avoided.

Root rots attack the taproot. Severe losses are reduced by a 6-year or longer crop rotation.

Snakeheads or *baldheads* may be seen just after the seedling emerges and may in severe form exhibit only a bare stump of the epicotyl with no sign of either primary leaves or terminal bud. Snakeheads are caused mainly by injury to the embryo in threshing, by insects such as the bean maggot, and by bacteria and fungi. The following conclusions seem justified:[159] (*a*) Of the

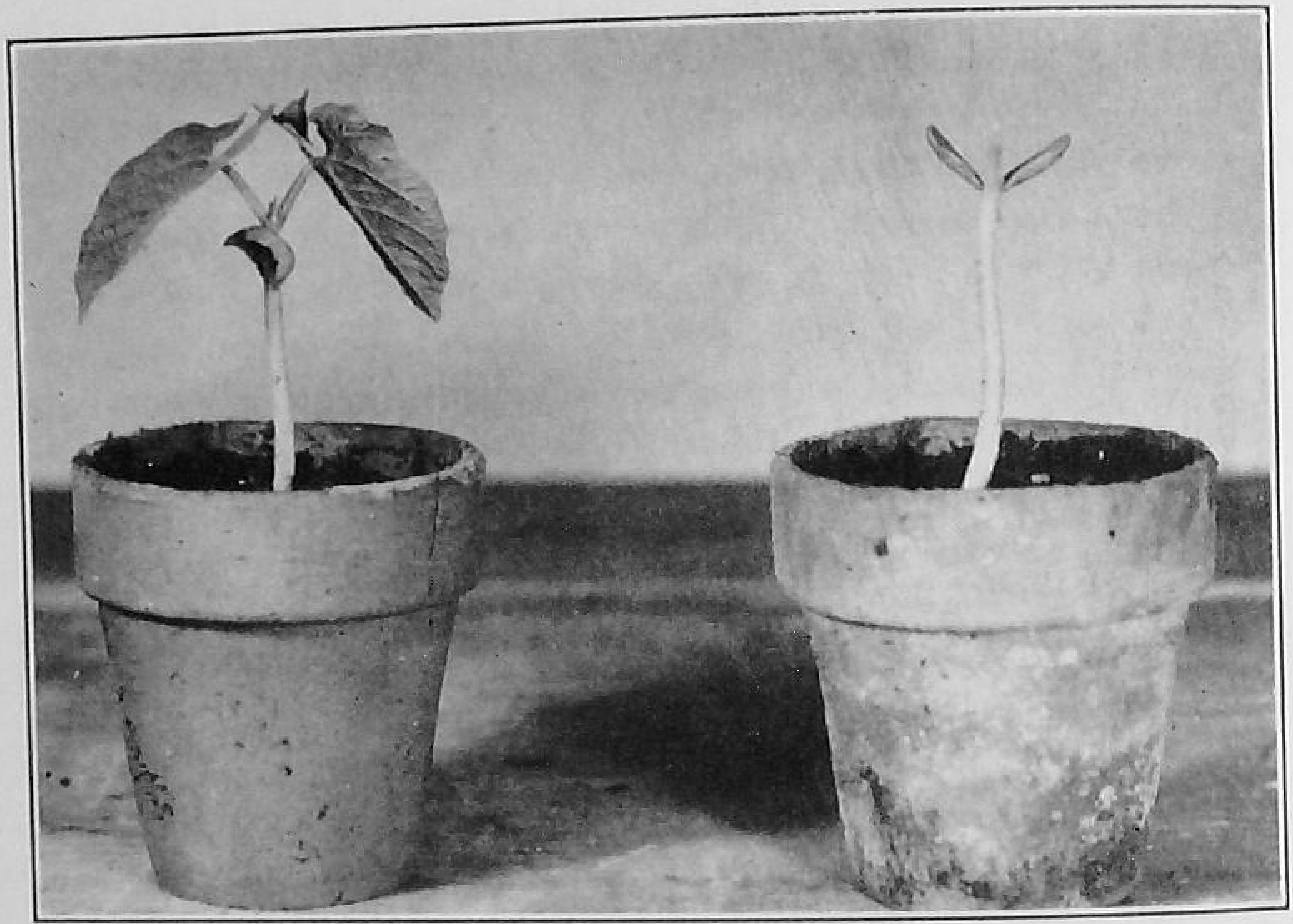

FIG. 26. *Left,* normal plant; *right,* snakehead plant minus both primary leaves and terminal bud.

various types of snakeheads in beans, only that involving the loss of both primary leaves causes much loss of yield. (*b*) Loss of the terminal bud tends to facilitate the development of axillary buds when its "dominance" is removed, and so increases stem number and pod-set. (*c*) The primary leaves are especially important in the early growth of the plant as they enhance development of the root system, draw nutrients from the seed cotyledons, and stimulate growth of the terminal bud or buds. (*d*) Loss of one primary leaf is offset by an accelerated growth of the remaining vegetative tissue. (*e*) True snakeheads (loss of both primary leaves) mature a few days later than other types, especially when the loss is accompanied by destruction of the terminal bud.

6 · BULB CROPS

ONIONS

Characteristic flavor accounts for the popularity of onions. Onions provide an appealing flavor when prepared in various ways as a fresh vegetable. Onions are also very useful for frying, boiling, baking, soup-making, in pickles, and for other purposes.

History

Origin and Early History

Middle Asia, comprising northwest India, Afghanistan, the Soviet Republics of Tajik and Uzbek, and western Tien Shan, is the primary center of origin of the bulb onion. Secondary centers of development and distribution are western Asia and the Mediterranean lands. The Welsh onion is probably of Chinese origin; "Welsh" here is a corruption of the German *walsch*, meaning "foreign," and does not refer to Wales.

The onion was cultivated by man before history was first recorded. In Egypt, it entered into many religious rites and festivals. The Israelites wandering in the wilderness complained bitterly to Moses because they had no onions: "We remember the fish which we did eat in Egypt freely; the cucumbers, and the melons, and the leeks, and the onion, and the garlick. . . ." In the time of Herodotus there was an inscription on the Great Pyramid stating the sum expended for the onions, radishes, and garlic that had been consumed by the laborers during its erection as 1,600 talents. During the great plague of London, the only places immune from contagion were the onion and garlic shops.

Modern Varieties

White Portugal probably was imported from Europe with the first shipments of vegetable seeds. Red Wethersfield, listed as

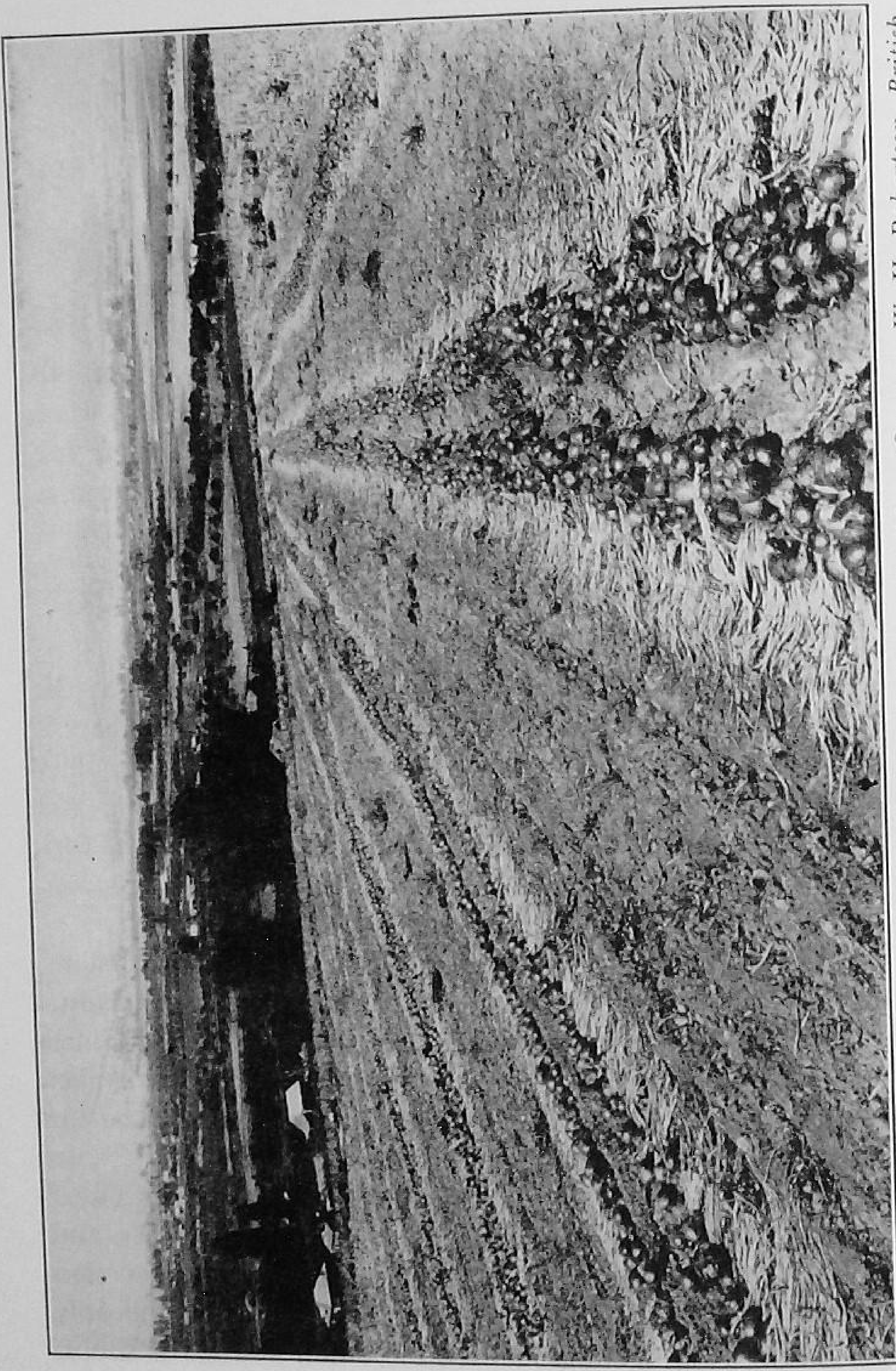

FIG. 27. An onion crop in the Okanagan Valley, British Columbia. (*Courtesy W. H. Robertson, British Columbia Department of Agriculture.*)

Large Red in 1834, was developed at Wethersfield, Conn., from a European variety. Red Creole has been grown on Bayou Lafourche, La., for over 100 years, and was developed from an Italian variety. Yellow Globe Danvers was selected before 1850 from the earlier-ripening, deeper bulbs of Common Yellow in Danvers and Peabody, Essex County, Mass. The name Southport is associated with the onion district of Southport, Conn. The yellow strain was listed in 1865 as Large Yellow, and in 1882 as Southport Yellow Globe. White Globe, which was listed in 1868, became Southport White Globe in 1875. Southport Red Globe, named in 1873, is probably derived from Red Wethersfield.

Yellow Bermuda, listed in 1888, came from Teneriffe or Italy. Ohio Yellow Globe was first listed in 1889 as Michigan Yellow Globe. California Early Red, selected from Red Italian Tripoli, was listed in 1890. Australian Brown appeared in 1897 as a new name for the product of Brown Spanish seed imported from Australia. Crystal Wax was listed in 1897 and White Creole in 1904. Mountain Danvers, selected from Yellow Globe Danvers, appeared in 1914. Ebenezer was selected in the Ebenezer section near Buffalo from a variety imported by German settlers.

Sweet Spanish (Valencia) came from Spain in 1916 and has been improved through strains (e.g., Riverside, Utah) developed here. In 1925 the Barteldes Seed Co. imported Valencia Grano 9452; the New Mexico Station improved the shape and named it Early Grano. Early Yellow Globe, selected from Extra Early Yellow (selected from Yellow Globe Danvers in Orange County, N. Y.), was first listed in 1931.

Excel, which was introduced in 1947, is a selection from Yellow Bermuda, by the U. S. Department of Agriculture and the Texas Experiment Station. San Joaquin, bred by G. N. Davis, University of California, and H. A. Jones, U. S. Department of Agriculture, came from a cross of Stockton G36 (a mild-flavored nonbolting strain) and Early Grano.

A number of hybrids are now available, e.g., Asgrow Y-40 and Asgrow Y-41 (both of Early Yellow Globe type) and Asgrow Y-42 (Sweet Spanish type).

Classification and Varieties

1a. Propagated from seed and grown as annuals (*Allium cepa*).[90]
  2a. Dry bulb scales yellow or brown.
    3a. Scales solid medium brown, oblate............Australian Brown
    3b. Scales yellow.
      4a. Thick flat to medium oblate.
        5a. Thick flat, light straw-yellow scales, mild flavor Yellow Bermuda
        5b. Medium oblate, pinkish-yellow scales, strong flavor Ebenezer
      4b. Not thick flat to medium oblate.
        5a. Deep oblate.
          6a. Scales light to medium yellow....Early Yellow Globe
          6b. Scales medium brownish-yellow....Mountain Danvers
        5b. Not deep oblate.
          6a. Obovate (flattened base).........Ohio Yellow Globe
          6b. Not obovate.
            7a. Ovate (flattened upper half)..........Early Grano
            7b. Not ovate.
              8a. Round, medium brownish-yellow scales Yellow Globe Danvers
              8b. Oval.
                9a. Medium size.
                  10a. Scales medium yellow and medium thick........Southport Yellow Globe
                  10b. Scales deep yellow and thick Brigham Yellow Globe
                9b. Large size, scales brownish yellow, flavor mild.....................Sweet Spanish
  2b. Dry scales not yellow or brown.
    3a. Dry bulb scales white.
      4a. Flat, large diameter, mild flavor................Crystal Wax
      4b. Not flat.
        5a. Thick flat to oblate.
          6a. Thick flat, early maturing.............White Creole
          6b. Oblate, late maturing................White Portugal
        5b. Deep oblate to round.
          6a. Medium size, strong flavor....Southport White Globe
          6b. Large size, mild flavor..........White Sweet Spanish
    3b. Dry bulb scales red or purple.
      4a. Mild flavor, soft flesh.
        5a. Thick flat, large size...............California Early Red
        5b. Torpedo or long oval......................Italian Red
      4b. Strong flavor, firm flesh.
        5a. Thick flat, large size..................Red Wethersfield
        5b. Not thick flat.

6*a*. Thick flat to oblate, buff red............Red Creole
6*b*. Round to oval, dark purplish red
Southport Red Globe

Note: The foregoing list is for the chief varieties grown on this continent. Besides these there are many minor ones and numerous English varieties, such as Ailsa Craig, Bedfordshire Champion, Excelsior, and James Keeping. The Tripoli group is important in Europe.

1*b*. Propagated from seed and grown as a hardy perennial or winter annual, or increased by division (*Allium fistulosum*). Not bulb forming; used as a very early bunching onion; adapted to forcing in a greenhouse in winter; often called cibol: White Welsh, Japanese Bunching, Nebuka.
1*c*. Propagated by division (*Allium cepa solaninum*). No top sets or seed; increased by division, splitting, or branching of the "bulbs" at the base of the plant into "bulblets"; not so hardy as White Welsh or Egyptian, but sometimes winters successfully: Yellow, Red, and White Multiplier.
1*d*. Propagated by top sets (*Allium cepa viviparum*). Sets (little bulbs or bulbels) produced in clusters on top of the plant in place of flower umbels, removed from the stalk, and planted in the fall for the production of green onions the next spring; the bottom also divisible; perennial; winter hardy; adapted to forcing in a greenhouse in winter: Egyptian or Perennial Tree Onion.
1*e*. Shallot (*Allium ascalonicum*). Distinct (see Growing Green Bunch Onions) but often loosely used.

Australian Brown is grown chiefly on the West Coast, where, because it remains marketable for long periods under fairly warm, humid conditions in winter, it is a major late-storage variety. *California Early Red* is grown chiefly as a nonbolting, early-intermediate crop in the interior valleys of central California for immediate local use.

Yellow Bermuda is a leader in the South, where the plants grow through the winter. *Crystal Wax* is adapted to the same regions but is white. *Excel,* a nonbolting, high-yielding variety, is supplanting older Bermuda types in Texas. *Early Grano* is adapted to the South where it may be grown through the winter and to northern areas where plants are set early in the spring. *San Joaquin* resembles Early Grano but the bulbs are larger.

Early Yellow Globe ripens about 2 weeks earlier than *Yellow Globe Danvers.* It is not adapted to the South because of the length of day required for bulb formation. *Ebenezer* provides most of the yellow sets, as it makes nearly round, bright yellowish-buff ones of good keeping qualities, but is not adapted to the South. It is also grown from seed for storage, but when

grown on marsh land, at least, many of the flat bulbs go through the grader.

Italian Red is adapted to central California as a late-intermediate, nonbolting crop for local consumption. *Mountain Danvers* is grown chiefly in the higher altitudes of Colorado and other mountain states. *Brigham Yellow Globe* is especially adapted to muck or peat soils in northern areas.

Red Creole is popular for home and market in the New Orleans, La., area. It keeps better in open sheds or barns during the humid summers than any other variety. *White Creole* is adapted to the same region and is preferred for cooking because of the white flesh. *Red Wethersfield* is a productive and good storage variety much used for red onion sets but is not adapted to the South.

Southport Red Globe does not mature well in the South, but the bulk of the crop is sold there as discrimination against the red color is not so great as in northern markets. Clean bulbs in good condition of *Southport White Globe* usually command a premium on the market but are difficult to produce, because the white color is easily spoiled by sunburn, greening, or soil discoloration. This variety produces excellent green bunch onions from seed, as less skinning is needed to produce the desired white basal swelling. It is not adapted to the South. It is useful for dehydration, because of its high dry-matter content, lack of objectionable color, and high pungency. *Southport Yellow Globe* is late-maturing and productive and, when properly matured, stores well. It is not adapted to areas south of the 36° parallel.

Sweet Spanish is adapted to regions with a long, cool, growing season, a minimum day length of more than 13 hours, high fertility, abundant rainfall or irrigation during the growing season, and a dry period during maturity. The best crops are grown in irrigated sections of the western mountain and West Coast states, though good bulbs are grown from transplants in northern areas. It is not a long-storage variety. It is greatly esteemed for salads because of its mild-flavored, almost white flesh. The *Utah strain* is more uniform and better colored than most other Sweet Spanish strains. *White Sweet Spanish* is slightly earlier.

White Portugal (*Silverskin*) is widely used for white sets and picklers, as the small sets are nearly round and store well. It is not adapted to the South.

Plant Characteristics

Seed Germination and Seedling Development

At germination the cotyledon is in the form of a closed loop, with its tip still embedded in the endosperm and seed coat from which it obtains nourishment. On loose soils like muck or sand the endosperm and seed coat are pulled from the ground, but on the heavier soils they may remain below ground. As soon as the cotyledon has absorbed all the nourishment within the endosperm, the tip or portion within the seed withers and becomes detached from the seed coat. This stage of development is known as the "knee stage." At the other end, or base, of the cotyledon where it joins the hypocotyl or exposed portion of the primary root, there appears a longitudinal slit; through this the first foliage leaf emerges.

Two stocks of onion seeds were stored for periods varying from 1 day to 4 weeks, at 50°, 70°, 85°, and 100°F., in sealed desiccators in which the relative humidity was maintained at 0, 50, and 100 percent by use of sulfuric acid solutions.[69] Increases in temperature and humidity caused decreases in the total number of sprouts and in the number of normal seedlings, and increases in the number of abnormal seedlings. Failure of knee formation was associated with the failure of critical cells of the cotyledon to enlarge and cause the cotyledon to bend. Root elongation and knee formation may possibly be controlled by growth substances, the production or transport of which is prevented by light. Also, abnormalities often seen in onion seedlings may result from similar deficiencies in physiological processes.

Roots

Two sets of roots are produced: one at the time of germination, functioning from then until the formation of the bulb; and the second at the time of formation of the bulb, functioning from then until the plant dies. The older roots, which arise from the center of the stem plate, tend to die early and are replaced by new roots from the margin of the stem plate.

At maturity, most roots are only 6–8 inches deep. The type of development varies with soil and other conditions, but the feeding range is quite limited. The root system of scallions

(thick necks) is larger and remains alive longer than that of normally bulbing plants.

LEAVES

In the normally matured bulb, about half the weight consists of the inner-leaf sheaths with aborted blades. If the bulb ripens properly, each inner leaf is completely enclosed within the one surrounding it. The outer leaves are the oldest and surround the younger leaves by their sheaths (swollen and expanded leaf-bases). After the leaf-bases have thickened, they become the scales of the onion bulb. If the blades of the inner leaves continue to develop, scallions that do not ripen properly are formed.

Yellowing of the tips and rapid death of the leaves are results of mildew, fusarium rot, and white rot. Yellowing of the leaves and stunting of the plant are symptomatic of root-knot, yellow dwarf, and pink root. A whitening of the foliage is due to the feeding of thrips.

BULB

Factors favoring large bulbs within a strain are: early planting; good spacing; early elimination of weeds; prevention of damage from blowing soil particles, diseases, and pests; adequate soil moisture for quick resumption of growth after transplanting and for continuous growth until bulb development is almost complete; avoidance of too high a water table; growing after a crop that has no detrimental residual effect; soil reaction of *p*H 6.0–7.0; ample supplies of minor elements; and optimum amounts and ratios of nitrogen, phosphoric acid, and potassium.

Larger bulbs are produced: from transplants than from seed sown in the field on the same date the transplants are set, particularly with late, large-bulb varieties; by unpruned plants than by those in which some of the foliage and roots are removed when planting; by early transplanting if doubling, splitting, or seedstems are involved; by large-sized plants than by small; by plants grown in a cool instead of a warm greenhouse; by planting 1½ inches rather than 3 inches deep; and by wider spacing.

When the onion is grown in the South during fall and winter or in northern areas in greenhouses in winter, no bulbs are

formed. A certain number of hours of light each day is necessary for bulb formation (see Climate).

Growing Large Onions from Seed Sown Outdoors

Most onions grown for late market or storage are seeded in the field. The seed is sown as early in the spring as weather and soil conditions permit in order that the plants get a good start before the hot weather arrives and because a long season is needed. The seedlings are highly resistant to spring frosts. Late-spring seeding results in less mature bulbs, poor keeping quality, and smaller size.

Dry weather early in the spring has a marked adverse effect. Usually the seed is sown shallow and, hence, depends on rain for moisture to germinate. Even in irrigated areas, rain is important for germination. Fall irrigation helps provide a moist seedbed, but invariably the topmost layer of soil dries out before the seeds sprout. Later in the spring, irrigation water can be used when danger of washing out the seedings is less great.

Seeding should be done soon after the seedbed is prepared. Only as much land should be prepared as can be sown immediately. This avoids drying out of the top soil before the seed is sown and encourages direct contact of the seed with moist soil. The seed is sown about ¾ inch deep.

The usual spacing of rows is 12–18 inches. Many growers on muck space the rows 16 inches apart, except for leaving 20 inches between rows where the machine wheels can run. About 2½–4 pounds of seed are sown per acre, with single- or multiple-row drills. When the onion maggot is troublesome, thicker seeding may be desirable. Thick seeding, because of the crowding of the bulbs, tends to give more mature but smaller and more uneven bulbs.

The seed is sown by means of various types of seed drills that range from a single hand drill to gang-drill equipment. With a single hand drill one man can easily plant 1 acre in a day. Gang drills, which contain two or more seed drills that are drawn by tractors, are employed on large acreages where their use saves time. Furthermore, they space the rows accurately across the field, so that cultivation equipment, which covers the same number of rows as have been seeded, can follow up in perfect alignment with the rows of onions.

Thinning

If large uniform bulbs are wanted, the plants should stand at least 3 inches apart in the row, especially on the heavier soils. Seeding may be done in a broad row, and the plants may be thinned to 2 inches each way. At maturity the bulbs tend to push each other up out of the ground under this system, and they are likely to ripen better than they sometimes do in single rows.

Thinning, if practiced, should preferably be done before the onions are as large as lead pencils, for, if the plants are very thick, they soon interfere with one another, and surplus plants have the same effect as weeds. If maggots are prevalent it is wise to delay thinning until the second generation of them has emerged. Thinning is best done when the soil is moist, care being taken to disturb the roots of plants that are left as little as possible. Growth is stunted if the roots are loosened in warm weather. A sharpened putty knife is a good thinning tool.

The objection to thinning is the expense. Unless the small onion plants are bunched in the row or spaced very closely after the period of maggot damage has passed, thinning is seldom profitable commercially. Good yields of large onions can usually be obtained by close estimation of seeding rate, soil fertility, and probable germination and survival of the seedlings.

Growing Picklers from Seed Sown Outdoors

For picklers, the seed is sown rather thickly at the rate of 10–15 pounds per acre. Thinning is not practiced. Harvesting is done when most bulbs have reached the size desired or have ripened in late summer.

Growing Large Onions from Transplants

Growing onions by the transplant method consists in starting the plants in seedbeds and in setting them in the field when they are large enough. On about 25 percent of the onion acreage in the United States this method is now used. The chief areas growing the commercial transplant crop are Texas, Louisiana, and California.

The chief merits of this method are earlier maturity, larger bulbs, greater uniformity in stand and size, higher yields, less seed, and greater freedom from smut, maggots, and thrips. The chief drawbacks are that much time, trouble, and equipment are necessary to grow the plants, and transplanting by hand is laborious.

Southern Transplants

Growing onion plants for shipment is a considerable industry in south Texas, Georgia, and some other southern states. Often growers specialize in this type of business to the exclusion of growing dry bulbs; others conduct both enterprises. Some growers specialize in carlot or truck shipments; others confine their activities to mail-order and express shipments. Growers catering to small orders often ship plants 8 months in the year and plant and have seedbeds 10 months. Shipments go to every state, as well as to Canada and Cuba. Peak shipments of the plants occur in late winter or early spring, when the northern demand is greatest.

About 20 pounds of seed are sown per acre of seedbed, yielding about 1 million plants or enough of a good size to set 10–12 acres of plants 4 inches apart in rows 14–16 inches apart.

Growing Transplants for Local Use

About 2 pounds of seed are sown for every acre of the transplanted crop. Most growers expect to obtain enough plants from 1 acre of seedbed to set 10 acres.

In south Texas, the seed is usually sown September 1–25; in Louisiana, from October 1–15; and in California, from September 1 to October 1. In the North, the seed is usually sown in coldframes, greenhouses, or hotbeds 10–12 weeks before the plants are to be set in the field. Seed is usually sown thinly (10–12 seeds to the inch). Precautions should be taken against damping-off. The best seedlings are produced at cool temperatures, i.e., 50°F. at night and 60–65°F. during the day. The plants are set in the field in early spring. If the seedlings are tender, they are hardened somewhat before they are planted in the open by watering less frequently and by exposing to night temperatures of 40–45°F. for a week to 10 days.

Time of Setting Transplants

In northern areas, planting early in the spring promotes strong root systems before the warm days of summer. Plants so equipped make stronger growth than those set late. The soil should be moist at planting time but not so wet that it cakes when handled.

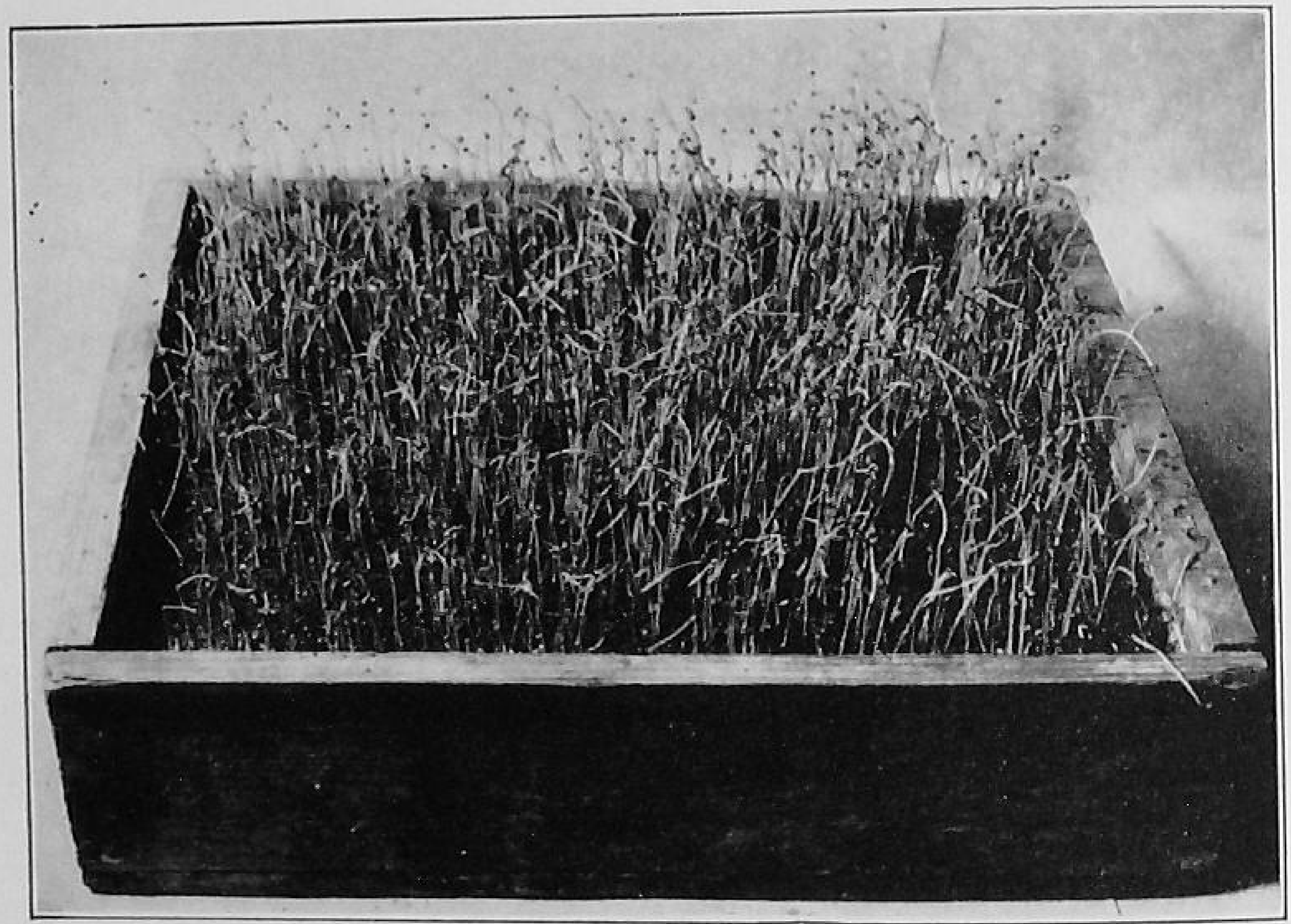

Fig. 28. Seedling onions in an early stage of one transplanting method. Note the seed at the tops of the plants.

In Louisiana, plants are set in the field between December 20 and January 15. In Texas and California transplanting is usually done during November and December, but it may extend into early January or even later.

Early plantings of medium-size plants usually produce heavier crops than late plantings. Generally, seedlings make very little growth aboveground during the winter in central California, southern Nevada, southern Utah, and other places with a similar climate, but conditions are usually favorable for root development. Plants set early develop extensive root systems during the winter, so that they grow rapidly when the weather becomes warm in early spring.

Methods of Setting Transplants [205]

In Texas, the seedlings are pulled, pruned, and placed in baskets or crates; then they are distributed ahead of the planter along 3 rows at a time. All transplanting is done by hand. A short stick or dibble is used to make a hole and to press the soil around the plant.

To facilitate irrigation on the uplands in Texas, low ridges are made 14–20 inches apart; the seedlings are planted 1 row to a ridge. One method of marking the rows is to use a lightweight metal or wooden roller having slats 3½–4 inches apart, the distance apart the plants are to be set in the row. On the bottom lands, where the onions are grown in flat beds between raised borders, very shallow furrows are made about a foot apart to mark the rows.

In California, by the use of a small plow a furrow slice is thrown away from each side of the raised bed at the top. The seedlings are laid against the side of the furrow about 3 inches apart and at a 45° angle, with the tops toward the center of the bed. The roots are then covered, a lister or cultivator being used; and, if necessary, water is run between the beds to settle the soil around the roots. The plants are set so that the rows will be 8–10 inches apart on the bed. In the Coachella Valley onions are grown in single rows on low ridges. On the Delta peat soils the crop is set on the level.

In Louisiana, plants are set about 4 inches apart in single rows on raised beds which are about 3½ feet apart. Raised beds provide drainage. In the center of the ridge holes are made into which the seedlings are dropped; then the soil is firmed about them.

The self-steering and self-propelled celery transplanter may be used to set the transplants in the field.

Depth of Setting Transplants

In Montana,[367] shallow planting (1½ inches) produced more flat, fewer round, and fewer elongated onions than deep planting (3 inches). More onions were regular in shape from the shallow planting, but there were more doubles. Greater yields of marketable Southport Yellow Globe were obtained from the shallow planting. With Sweet Spanish, in a year when the crop

was injured by severe hail in midsummer, the deeper planting gave greater yields.

Spacing Transplants

Transplant onions are set 4–6 inches apart in rows 1–2 feet apart. Usually the closer the spacing the higher the yield and the smaller the bulbs. At 4×14 inches, 112,000 plants are needed per acre. To calculate the number of plants needed for an acre multiply the space between the plants in the row by the space between rows, in feet, and divide into 43,560, the number of square feet in an acre.

Bolting in Transplants

In most areas where the transplant crop is overwintered, a high percentage of the plants may produce seedstems and be a loss. Sweet Spanish, Crystal Wax, Yellow Bermuda, Excel, and Creole bolt rather readily; California Early Red, Calred, Stockton Yellow Globe, Early Grano, San Joaquin, and Italian Red do not bolt so readily.[205]

Temperature, as well as the variety and the size of the overwintered plant, is important in determining the amount of bolting. The most bolting occurs after a warm late fall and a cold late spring. A warm fall favors the development of a large plant for overwintering, and the combination of a large plant and a cool spring encourages bolting. Conversely, the fewest bolters occur after a cool fall and a warm spring. The effect of a few degrees difference in temperature on bolting is often evident in commercial fields. In areas where 2 rows of transplants are grown on raised beds running east and west, the north row often has more bolters than the south. The north side of the bed is cooler because it does not get the direct rays of the sun and also is shaded by the south row. More bolting occurs on heavy than on light soils, and usually there are more bolters in low, moist spots in the field than in well-drained parts. In south Texas, a few days' delay in time of seeding in the nursery or in transplanting will often considerably reduce the amount of bolting.[205]

Growing Ripe Onions from Dry Sets

Sets planted in the spring produce green onions quickly, or, if left to grow, they produce large, dry onions earlier than those grown from seed. Advantages of sets, in the kinds available, as compared with transplanting, are: sets can be planted earlier; it is not necessary to delay planting while waiting for the plants to attain proper size; planting is quicker; and the trouble and expense of growing seedlings is avoided.

The set method is more expensive than seeding because of the cost of sets but is a surer way to produce a crop under adverse conditions. Stored food in the sets gives the plants a strong start, and so they can make much of their growth when the weather is cool and the soil moist. The crop is about 3–4 weeks earlier than that from seed. An onion-set machine enables planting to be done quickly. Sets are immune to smut.

Best Size of Set

Medium-size sets, ½–¾ inch diameter, are the best in producing ripe onions. A smaller size (⅜–½ inch) is preferable to one over ¾ inch. Large sets often send up seedstems and produce bulbs that are worthless as ripe onions. Very small sets make a weak start, produce small bulbs, and give a low yield.

Bolting in Sets

Large sets (¾ inch and over) produce many undesirable bolters.

Sets stored at 40–50°F. produce more bolters than at 30–32°F. At 60–70°F. fewer bolters, but more shriveling and sprouting, results than at 30–32°F. After sets are planted, an extended period of 50–60°F. or lower is necessary for bolting. Ebenezer sets produce less bolters than Yellow Globe or Red Wethersfield sets.

Time and Depth of Planting Sets

Sets should be planted early in the spring. A few degrees of frost will not injure the young plants. Sets planted 1–2 inches deep give better results than those planted on the level and later

hilled or than those thrown into a furrow 3 inches deep. To obtain a long, palatable portion in bunch onions the sets are set upright and somewhat deeper than for ripe onions.

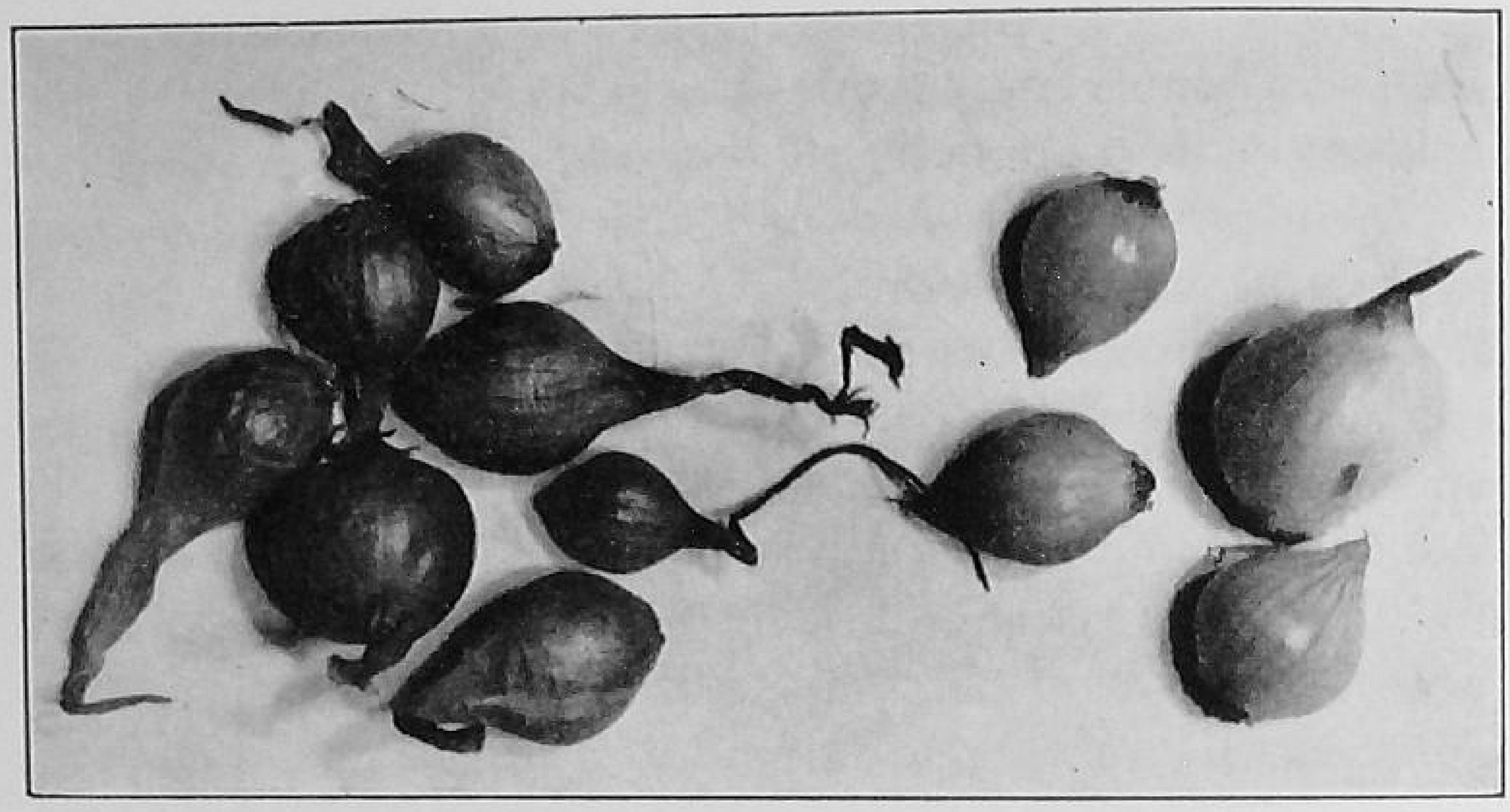

FIG. 29. Onion sets.

Spacing Sets

The rows are spaced about 14 inches apart. For the production of large onions, sets are planted 2–4 inches apart in single rows; for bunching onions, 1–2 inches. Depending on size of sets and spacing, 15–30 bushels are needed for an acre.

Machine Planting of Sets

It is not necessary to place the set in an upright position if mature bulbs are to be produced. Commercial growers use 1- or 2-row set planters which open the row, drop the sets, and cover them with soil. On the average, ten men will plant an acre in a day, whereas one man with a machine will do the same.

Growing Green Bunch Onions

Green or bunch onions are grown in most home gardens and are also extensively produced by market gardeners.

Bunch Onions from Sets

A simple way to grow green onions is to plant sets early in spring and pull the green onions when they attain desired size.

The larger the sets, the quicker they produce green onions of edible size. But unless green onions grown from large sets are pulled promptly, they often bolt and become pungent and tough. Medium-size sets produce green onions in 5–7 weeks.

Bunch Onions from Seed

Bunch onions grown from seed sown in the open are not ready until later than those produced from sets, and thus they prolong the bunching season. Market gardeners may harvest bunch onions as a thinning process for the bulb crop.

Greenhouse Forcing of Storage Bulbs

The forcing of storage bulbs is a quick and relatively easy method of obtaining green onions for home consumption or for sale on the local market during winter and early spring. Mature, storage bulbs are planted shallow, side by side, in soil in a greenhouse, hotbed, or coldframe. The soil in raised greenhouse benches should be about 2 inches deep. Bulbs graded No. 1 Small are the most economical as they are cheaper than No. 1 Large and produce more green onions per square foot of greenhouse space.

After planting, a temperature of 60–65°F. is maintained and water is supplied as needed. When the green shoots are of acceptable market size, the bulbs are cross-sectioned with a large knife through the center. The lower half is left rooted in the soil; the upper half is removed from the shoots and discarded. The shoots are then cleaned and marketed like other green-onion types.

Egyptian or Perennial Tree Onion

Like the cibol type, the Egyptian or perennial tree onion is often called winter onion because it survives the winter outdoors. A cluster of little bulbs, or top-sets, is produced at the top of the stalk, where seed is produced in an ordinary onion. The bottom also divides, as in multiplier onions, but large bulbs are not produced.

The top-sets or bottom divisions are planted in early fall or spring, preferably the former, in furrows about 4 inches deep. The deep planting promotes long, white stems. The spacing is about an inch apart in the row for green bunch onions, but

if the plants are to be left to produce clusters of small bulbs the spacing is 6 inches. When frost leaves the ground in spring the tops start to grow. Those produced from divisions are soon ready to use, and those from top-sets follow shortly after. This type becomes very pungent, but early in the season is of good palatability.

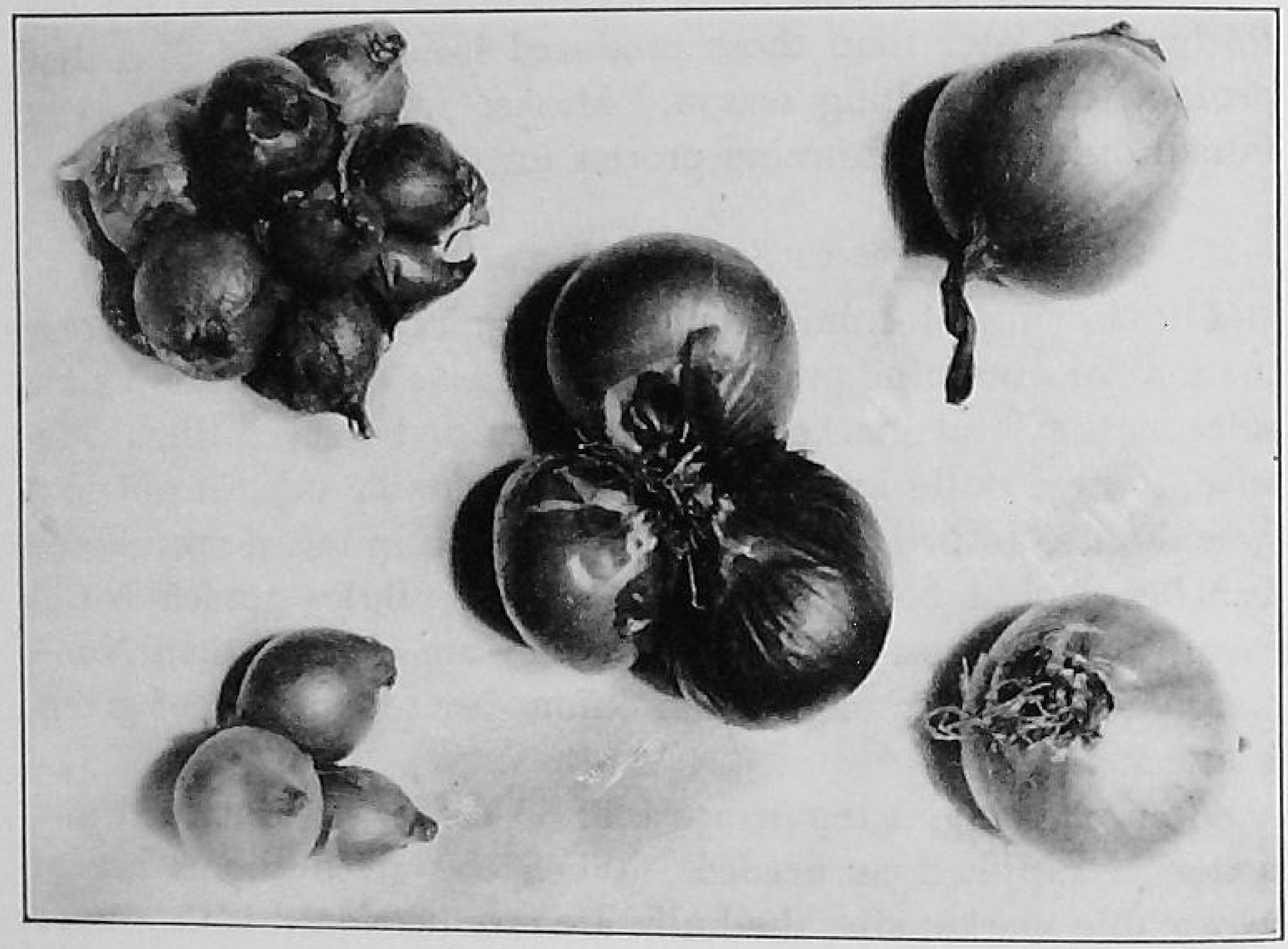

Fig. 30. Multiplier onions.

Multiplier or Potato Onion

The multiplier onion is increased by separation of the compact clusters at the base of the plant. The small bulb or set grows into a large one which again breaks up into small ones. The multiplier onion often winters well when planted in the fall and mulched.

Cibol, White Welsh, or Japanese Bunching Onion

The cibol onion is propagated, preferably in autumn, by seed and grown as a perennial or winter annual, or is increased by division of the clumps. It is extremely hardy and highly resistant to disease and insect pests. Bulbs are not formed, but the stems are useful as green bunch onions very early in the season. Later, the flavor is quite strong.

SHALLOTS

The name "shallot" is often loosely used for any green bunch onion. Louisiana produces 90 percent or more of the shallots grown in the United States.

Two commercial types of shallots are grown in Louisiana,

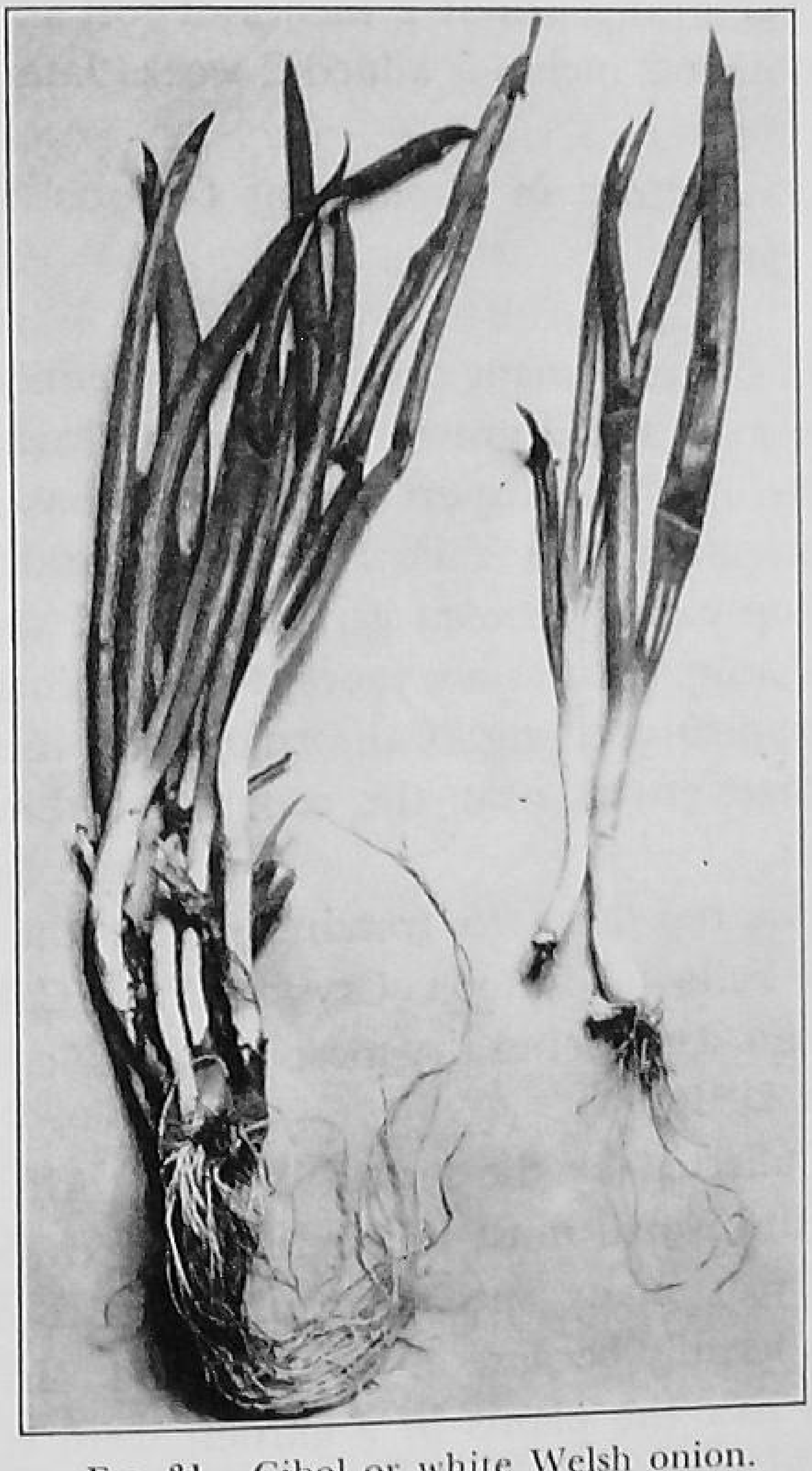

FIG. 31. Cibol or white Welsh onion.

i.e., pin leaved and flat leaved. *Louisiana Pearl* white shallot is resistant but not immune to pink root. *Louisiana Evergreen* (Louisiana Pearl No. 1 × perennial Nebuka), a home garden and market type, not well adapted to shipment, is highly resistant to pink root, and it grows and remains green throughout the year. The Evergreen type is propagated by division of the green cluster (stool) of plants. It does not make dry sets like the Louisiana white type.

The true shallot, upon reaching maturity, produces small, pointed, white bulbs. The larger bulbs produce more plants per bulb, and the plants are taller with more leaves. The clumps are divided and spaced 6–10 inches apart in the row. The spacing between rows is usually greater than with the onion because shallots are blanched by banking with soil. Five weeks or so before harvesting, about 2 inches of soil is drawn against the plants; another 2 inches is added 2 weeks later.

Factors in Producing Onions

Climate

The best root development occurs at soil temperatures of 54–68°F. and the most rapid growth of tops, at least during early growth, at 68–70°F. Southport Red Globe has a lower temperature requirement than Yellow Bermuda, and the optimum for root and top varies between varieties. Red varieties maturing under low temperatures are more deeply colored than those under high temperatures; e.g., California Early Red bulbs are a darker red when grown near the cool coast than in the hot interior valleys.

Differences in resistance to freezing occur, the soft-textured types, such as Yellow Bermuda, Crystal Wax, California Early Red, and Italian Red, being the most susceptible. Onions usually withstand 28°F.

Onions are affected by the length of day. All varieties that grow well in the North must be seeded early in order to form bulbs. Each year many specimens of Spanish onions refuse to form bulbs, usually because of late planting. In New Hampshire [176] about half the plants in a garden were scallions when sown the second week in June, and all of them made bulbs when sown on or before mid-May. Also, seed of Yellow Globe Danvers type sown in July for sets refused to form even tiny bulbs.

Increasing the length of photoperiod hastens maturity. The minimum photoperiods for 100 percent normal bulbs of different varieties are given below.[245]

12 hours: Yellow Bermuda, White Creole, and Early Grano.

13 hours: California Early Red, Yellow Strasburg, Ebenezer, and Yellow Danvers Flat.

13.5 hours: Early Yellow Globe, Mountain Danvers, Ohio Yellow Globe, Australian Brown, White Portugal, Southport Yellow Globe, and Sweet Spanish (strain 1).

14 hours: Red Wethersfield, Southport Red Globe, and Italian Red.

14.25 hours: Yellow Globe Danvers.

Normal day (maximum of 14.9 hours): Yellow Flat Giant, Yellow Flat Dutch (strain 2), and Sweet Spanish (strain 2).

16 hours: Bloodred Flat Dutch, Yellow Flat Dutch (strain 1), Zittan, and Wolska.

Varietal season of maturity depends upon the response to length of day and upon the rate of development during each length of day in excess of the indicated minimum needed for bulb formation. Thus, Ebenezer matures its bulbs in advance of Sweet Spanish in every photoperiod beyond 13 hours. Relatively high temperature, as well as a long photoperiod, is essential for bulb formation in certain varieties that are commonly grown under long-day conditions. At 50–60°F. with a short day (9–12 hours) onion plants bolt readily, but at 70–80°F. they do not, with either a short day or a 15-hour day. High temperature plus a long day results in maturation of the crop, but even with a long day, if the temperature is too low, maturation does not occur.

Soil

Soil for onions should be rich in humus. Muck soils are commonly used. In loose, sandy, or muck soils bulbs may be grown thickly in the row without deformation, but in mineral soils, especially of the heavier types, the bulbs may become flat sided or top shaped if crowded in the row. Light sandy soils promote earlier maturity than heavier soils.

Soil preparation. Onions grown from seed need a finer degree of tilth than most crops. On loose, rich soil, discing may replace plowing, as onions thrive well on a hard bottom. A leveler or roller may be attached in front of the drills to level and compact the seedbed immediately before seeding. Fall plowing of mineral soils is wise as winter frosts help to pulverize the lumps and, also, the moisture from the melting snow is readily absorbed. Since early seeding is important to obtain good yields, land that does not drain well and remains wet in the spring or that is subject to flooding is not likely to be profitable for onions over a period of years.

Soil reaction. Lime should be applied only on soils more acid than pH 5.6. The optimum is pH 6.0–6.5. Shallow muck may settle to the point where marl, which underlies the muck, may be plowed to the surface and incorporated in the muck, making the soil alkaline and possibly rendering some of the minor elements unavailable. Very acid soils may cause the death of seedlings, and sets may grow well only for a short time, after which growth slows down, the tips of the older leaves turn yellow, and finally the entire leaf collapses and dries up.

Influence of previous crops. In Rhode Island, before sowing onions, various crops were grown in different plots for 2 years, and for the 8 preceding years the plots were given uniform treatment.[164] Yields were: 13 bushels of onions per acre after beet and cabbage, 14 after rutabaga, 17 after buckwheat (more when limed), 35 after potato, 87 after spring rye, 131 after corn, 143 after millet, 161 after onions, 175 after oats, 178 after red clover, 293 after timothy, 314 after alsike clover, 406 after timothy and redtop, and 412 after redtop. Onions thrive following grasses, cereals, and clovers.

Several years are necessary to get a piece of land into ideal condition for onions grown from seed. Onions may thrive better if grown successively upon the same land than if sown on new land each year, unless the land becomes infested with pests.

Windbreaks.[311] Seeded onions grow slowly at first and are easily injured if wind blows the dry muck so that it strikes the tender plants. Large areas of muck must be protected by windbreaks or damage may be severe. One windy day early in the season, if the surface of the muck is dry, may ruin acres of onions if they are not protected. The willow windbreak, although commonly planted, has some drawbacks. Willows soon grow tall, and growth at the base is not enough to break the wind adequately. Willows must be removed and replaced at relatively frequent intervals, especially if they are not trimmed regularly to keep them within bounds. Weeds that seed under the hedges add to the problem of weed control on the muck. The willow windbreak wastes valuable land; crops do not grow well within 15 feet of it on each side.

After years of relative freedom from wind injury, growers often consider removing aging willow windbreaks and depending on snow fences. In some fields, such a plan is good. But wind-

breaks are insurance. They cannot be installed after the wind starts; it is more profitable to maintain this protection for 5 years without needing it than to chance 1 year of nearly complete loss. Reseeded onions may not yield well if sown late. Onions on small areas of muck protected by trees rarely suffer from wind injury.

Manure and Fertilizer

Fertilizer requirements vary with the type of onion, type of soil, previous treatment, purpose for which the crop is grown, and many other factors.

Manure. About 10 tons of manure per acre should usually be applied to the crop preceding onions on mineral soils, and it is often wise to supplement this with fertilizer. Land that has been heavily manured for other crops for 2–3 years preceding onions is to be preferred to ordinary land manured in an attempt to make it rich enough for onions in 1 year.

Major elements. Nitrogen-starved plants are yellowish green, dwarfed, somewhat twisted or curled, and their necks do not soften or collapse but remain rigidly erect. Wet, cold soils or excessive water produce the same symptoms as nitrogen starvation. Small amounts of nitrogen may encourage early growth. Delayed or split applications of nitrogen may result in more immature bulbs than when all of it is applied before planting.

Sweet Spanish type onions need only 10–24 ppm. of nitrate nitrogen throughout growth, and high concentrations may be detrimental. For Globe onions, high concentrations of nitrate appear unnecessary.[357]

Bulbs produced on soil well supplied with phosphorus tend to be darker colored and have more dry scales per bulb, perhaps because of earlier maturity. On an acid soil with little organic matter, deficiency of potash may result in thin scales. Increasing the proportion of phosphoric acid to potash hastens maturity and so is often advisable on late plantings, on late-maturing varieties, and on very acid, alkaline, or poorly drained soils.

In California,[234] when 120 pounds of nitrogen and 120 pounds of phosphorus were applied per acre at transplanting time, the yield was higher than when applied 67 days later. Response to phosphorus depended on closeness of placement to the roots. It seemed best to apply fertilizer at the time of seeding or time

of transplanting 2 inches outside the plant row on the shoulder of the bed and 2 inches below the seed.

In New York it is reported: [221] (*a*) Potash did not increase yield on either 2- or 13-year-old muck. (*b*) During a cold, wet spring nitrogen increased the yield on both the 2-year and 12-year muck but was especially beneficial on the low *p*H 12-year muck. (*c*) Nitrogen applied as a sidedressing increased the yield on mucks of both ages, but when added without potash it tended to decrease the keeping quality. (*d*) The Elba area onions that received the most nitrogen and potash kept the best; the reverse was true of the Oswego area onions except where an acute nitrogen deficiency existed. The next year none of the treatments affected the keeping quality even though mineral nutrients were present in excess.

Virgin muck may have low levels of phosphate and potash, and varying lime content. The total nitrogen contained in the organic matter may be high but not readily available. The amount of extra nitrogen needed for a given crop is best determined by a soil or tissue test, appearance of the crop, and past experience. Some peat areas are basically water gardens.[131]

MINOR ELEMENTS. Certain muck areas produce bulbs of poor color and thin scales. The outer scales come off in handling, giving the bulbs a poor appearance and making them more subject to bruising. Applying 100 pounds per acre of powdered copper sulfate is often wise; the effect lasts for several years. Adding copper sulfate to other fertilizers on acid mucks and adding sulfur and manganese sulfate on alkaline mucks may increase the percentage of mature bulbs and result in a darker color of both yellow and red varieties, especially where onions develop poor color and thin outer scales.

The beneficial results of sulfur on slightly acid to alkaline, unproductive peats are largely due to the effect of the increased acidity on the availability of manganese. The cost of 100 pounds of manganese sulfate is much less than that of the ton or more of sulfur which would be needed to increase the acidity of the peat enough to improve the growth of onions. The manganese treatment can be delayed until the limits of the unproductive area are clearly demarked. For quick results when the soil is dry, it is better to apply the manganese sulfate in solution rather

than in a broadcast way and wait for rain to carry it to the root zone.

A deficiency of magnesium results in plants with an appearance similar to that from a very acid soil and with premature browning of the tips of the leaves. Applying dolomitic limestone, or spraying with magnesium sulfate (2 pounds dissolved in 10 gallons of water), is helpful.

CULTIVATION

Seeded onions may need cultivation about once every 10 days for a 3-month period, unless weed killers (Chapter 15) are applied. Deep cultivation is likely to reduce the yield on upland soils, but occasionally is beneficial, "hooks" being used, on compact, poorly aerated muck in a cool, wet year. Hand weeding in the rows, if practiced, should be done before the weeds are large enough to rob the onions of moisture, nutrients, and light. Also, if the weeds are allowed to become large, removal may disturb the roots of the onions and cause the bulbs to ripen before developing normal size.

IRRIGATION

SEEDED ONIONS. In irrigated areas, seeded onions are irrigated as soon as they are large enough so that implements can make furrows between the rows. The first irrigation is flushed over the field rapidly, and only between alternate rows, to avoid the shock often caused by excessive water. Later, the water is run between all rows. A simple test to determine if the soil has enough moisture is to take some soil from beside, and 4–6 inches below, the plants. If moisture is adequate the soil will ball when grasped by the hand and will not crumble when the hand pressure is released. The last irrigation is given in late summer. Cultivation also ceases then. Later irrigations or cultivations cause immature, thick-necked bulbs. Also, if the soil is allowed to remain firm after the last irrigation, the bulbs ripen sooner than if it is loose. The moisture should be reasonably constant; with drastic fluctuations the inner scales may split the outer ones, causing splits and doubles.

TRANSPLANTS.[205] Although onion seedlings will survive 12 days or more, after being transplanted to a very dry soil, such

practice always results in lower yields. Roots continue to arise from the stem plate at the base of the onion plant during most of the time that the plants are growing. Because new roots are not formed unless the zone from which they arise is in moist earth, the soil near the surface must be kept moist until the crop is nearly mature.

FIG. 32. Onions under overhead irrigation. (*Courtesy J. R. Van Haarlem, Horticultural Experiment Station, Vineland, Ont.*)

Most of the transplant crop of the Southwest and West is irrigated during part or all of the growing season. Onions must be kept growing steadily without any setbacks, as onions that start new growth after being retarded may split or double and thus produce a small yield of No. 1 bulbs.

On the sandy loams of southwest Texas, 5–8 irrigations are usually all that are needed between transplanting and harvest. More may be needed during seasons of heavy thrips infestation. From December to early March irrigations can be 6–10 weeks apart, but then the frequency must usually be increased to once every 5–14 days. In south Texas the especially strong winds prevalent at this time increase the water requirements.

Over-irrigation, as well as lack of water, may cause reduction in yields. The foliage of onions receiving excessive irrigation acquires a yellowish-green color.

When the plants start to mature, irrigation should be discontinued and the soil allowed to dry out as much as possible; otherwise a second root growth, which is difficult to stop, may start and complicate the process of properly curing the onions.

Ripening, Rolling the Tops, and Cutting Roots

When onion plants ripen properly, the leaves weaken in the region just above the bulb, and the top falls over while the leaves are still green. If the tops dry from the tips toward the base while standing erect, the neck is not closed, and the bulbs do not store well. Immature onions are thick-necked.

Rolling the tops. Rolling down the tops in late summer may hasten maturity, but tests question its value.

In Montana,[367] the first 2 years the tops were rolled about a week before the onions were pulled. Thereafter one rolling was 3 weeks before pulling, followed by another 10 days later. A small, metal barrel long enough to cover 2 rows at one time was used. It was heavy enough to bend the tops down without crushing the onions, but laid the thick-necked onions mostly on their sides without bending at the necks. In only 1 of 7 years did the rolled plots generally appear to be more mature, though in one other year rolling seemed to hasten the maturity of Ebenezer and Southport Yellow Globe but not of Prizetaker and Sweet Spanish. The keeping quality was not consistently affected. In two trials rolling impaired the keeping quality of Sweet Spanish. The rolled Ebenezer and Southport Yellow Globe onions kept better 1 year and more poorly 1 year than the unrolled. Hence rolling apparently has no value as an aid to storage; and with some varieties, like Sweet Spanish, it appears injurious. Rolling generally decreased yields. On the average the reduction was small with Prizetaker but was 10, 20, and 37 percent, respectively, for Southport Yellow Globe, Ebenezer, and Sweet Spanish. Thus rolling is not justified as it adds to the cost without benefiting the crop.

In Michigan,[160] rolling tended to produce neck rots.

Cutting roots. Some have thought that cutting the roots reduces the amount of nutrients taken from the soil, certain of which, especially nitrates, tend to retard maturity. Two methods of cutting the roots have been compared.[367] In "light cutting," the roots were cut by a knife thrust at an angle under the plants. The object was to sever about half the root system, thus reducing, without completely preventing, intake of moisture and nutrients. This method did not cause much wilting of tops. It did not hasten maturity. It reduced yield of Ebenezer and Southport Yellow Globe but had little effect with Prizetaker and

Sweet Spanish. In "heavy cutting," the roots were cut by a spade thrust into the ground at an angle. It caused the tops to wilt decidedly and seemed to hasten maturity but did not always improve keeping quality. In fact, with Southport Yellow Globe storage losses were greater. Cutting roots decreased the marketable yield 31–44 percent.

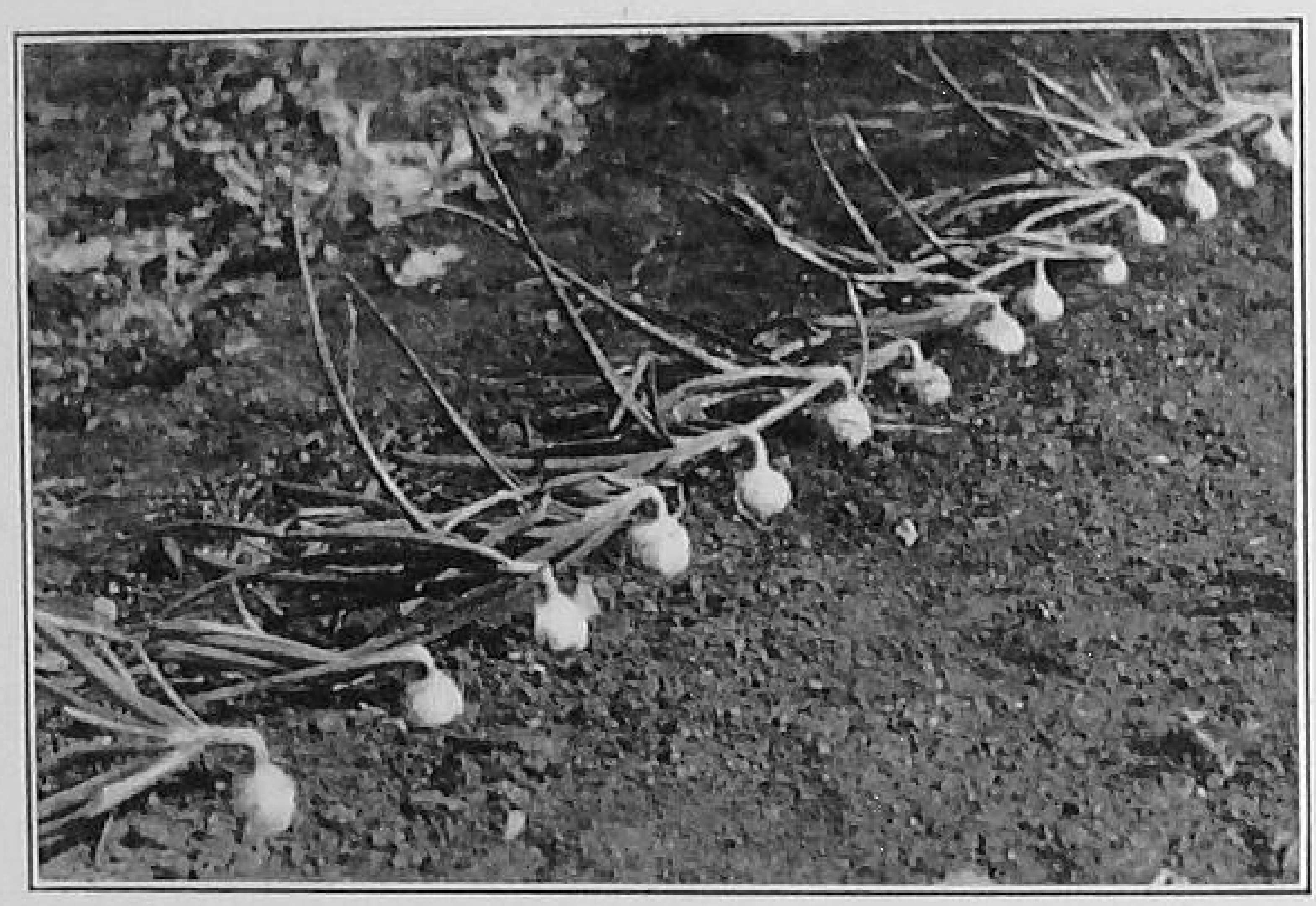

Fig. 33. Onion tops bent over in an attempt to encourage ripening.

Unless the plants are shallow, drawing soil away in late summer or early fall may help to encourage maturing of the bulbs. But this plan may result in sun damage.

Harvesting

Green bunch onions. Green bunch onions are harvested when they are the diameter of a lead pencil and until a small bulb is formed. Several pullings are usually made by hand, the largest plants being removed each time and the others being left to develop. The roots are trimmed and the outer skin is peeled off, leaving the stem clean and white. The onions are then tied in bunches, the number in each bunch depending on the size and local custom.

Ripe bulbs. A well-matured bulb is one that is firm and has the shape and color typical of the variety. Maturity is indicated by the tops drooping just above the bulb while the leaves are still green. Also, when a bulb completes its growth, the roots begin to die, and they lose their hold in the ground.

There is a gradual softening of the neck and a transfer of the soluble solids of the leaves into the bulb, so that the outer succulent layers of the bulb nearly close the opening over the leafless inner scales.

During the time when an onion growing normally becomes less firm at the neck as it matures and the top falls over, and immediately thereafter, food material is transferred rapidly from the top to the bulb. As a result the bulb increases rapidly in size. To obtain good yields most of this food transfer should take place before the onions are pulled.

Gradual drying of the leaves from the tips downward while the necks remain rigid, thick, and erect indicates abnormal ripening and usually poor keeping quality. Whole crops may ripen prematurely from the top downward because of thrips; such onions are undersized and undesirable for late storage. After the shriveling of the necks in normal ripening, the leaves gradually turn yellow, and finally the tops become dry and brown if the onions are not harvested first.

Premature death of the leaves causes the neck of the bulb to remain open and permits entrance of moisture and rot organisms. Open and thick-necked bulbs soon resume growth (sprout) or rot. When decay is not a factor, quicker sprouting results from the greater accessibility to oxygen of the central growing point in thick-necked bulbs than in those with well-closed necks. Because there are nearly always some "thick-necks," it is usually wise to begin pulling when 75 percent of the tops are down. If onions remain in the ground after they become mature, they may take root again and begin second growth, especially after rain, and their keeping quality is ruined. Onions pulled when slightly immature retain their outer skins better and are less likely to sprout and root when curing, but are not so solid as when fully mature and are more easily bruised. Conditions that delay maturity and curing result in softer bulbs.

The first few light frosts usually do little or no harm to onions, but heavy frosts are injurious, and so harvesting of ripe onions should not be delayed too late.

PULLING. If the bulbs are mature they pull easily by hand if the soil is not hard or compact. Several bulbs may be pulled at a time by taking hold of the tops. In some areas, culti-

vators with duck-foot shovel attachments are used to lift the bulbs. Good results are obtained by using machines to cut the root system and lift the bulbs to the soil surface or by using chisels to loosen the soil around the bulbs to make easier pulling by hand. Onion combines will lift, top, grade, and bag the bulbs in one operation.

TOPPING. Onions may be topped with shears, knives, or topping machines. The tops may be removed in the field, as they are gathered from the windrows, by twisting or by cutting ½–1 inch from the bulbs, or at the point the tops would normally fold over when mature. Twisting leaves the scales closed tightly at the top of the bulb, whereas cutting may leave them open and susceptible to entry of decay organisms. Cuts with the knife should be away from the bulb to prevent peeling part of it. Topping onions before pulling and lifting these bulbs with a tractor cultivator is successful in Utah.[388]

At Davis, Calif.,[187] Southport White Globe, San Joaquin, and Australian Brown onions were harvested at three stages of maturity, and topped at 0, 2, and 4 inches from the bulbs. If maturity is considered independent of length of neck, physiological shrinkage proved to be highest among bulbs harvested with tops up and green, intermediate for bulbs harvested with tops down and green, and lowest for those harvested with tops down and dry. Rot and total losses were lowest for bulbs harvested with tops down and dry, and highest for bulbs harvested with tops either down and green or up and green.

If length of topping is considered independent of maturity, the shorter toppings usually resulted in the least physiological shrinkage and generally less rot and total loss. Topping flush with the bulbs usually resulted in more shriveling but rotting was generally less than for longer-topped bulbs. A relation was noted between length of topping and maturity. For bulbs harvested with tops up and green a short topping length was superior; for bulbs harvested with tops down and dry the topping length had little influence on storage behavior. Results for bulbs harvested with tops down and green were not consistent.

YIELD. A yield of 1,000 bushels per acre is not uncommon. A grower on muck in Indiana is said to have grown 1,471 bushels on an acre.

Curing

A well-cured onion is firm, and the top of the bulb is not readily dented by thumb pressure. Unless well cured, onions will not keep, and so if bulbs are to be used during winter they must be thoroughly cured before being stored. Dry weather in early fall helps to mature and cure onions after pulling.

Windrow or field method. Usually 4–6 rows of bulbs are pulled and put together in a single windrow and left until the tops have wilted and partly dried. The tops provide partial protection from the sun (especially important with white varieties) and from light frosts, if they are placed so that they cover the bulbs in shingle fashion. They are usually left in this way for 5–10 days. It is sometimes wise at the last cultivation to draw a little soil over the developing bulbs of white sorts to protect them from the sun. Care must be taken that the onions are not frosted at night while they are curing. If it rains, the onions drying in the windrow should be turned (as with a wooden rake) to permit thorough drying on all sides, as otherwise much bulb discoloration may occur, rots may start, sprouting or rooting may take place in the moist soil, and the keeping quality is adversely affected. If handled when wet the onions may be discolored by the soil.

Onions are sometimes topped as they are pulled, and placed in open-mesh bags, or crates, which are left standing for 10–14 days to cure in the field if there is little fall rain. The bags should be raised off the soil and placed upright.

Crate method. After the tops are removed and after being spread out for a few hours to allow the dirt on the bulbs to dry in the sun, the bulbs are placed in shallow slatted trays (e.g., 4 feet × 3 feet × 3 inches) with lath bottoms spaced to provide ventilation. Laths, or 1 × 2 inch wooden strips, may be placed across the ends of the bottom for air circulation between the trays when these are stacked in tiers. The trays are then covered with canvas, building paper, or other material or brought indoors for curing.

Bulbs may also be spread out on a floor in a dry place indoors. White onions are especially difficult to cure in the field and so are often cured under cover.

Artificial curing. In California,[188] curing by forcing warm air, at 105–118°F., through open-mesh bags of bulbs was com-

pared with curing in the field in burlap bags and with curing directly in storage after harvesting and topping. The artificial curing saved much time; no bulbs showed heat injury from this 16-hour curing.

Storage

Onions should be thoroughly matured, cured, and dried before being stored. They should feel solid and should have tough clinging skins.

In cold storage, bagged onions are usually piled in pairs laid crosswise in stacks of 4–6 layers; 2–4 inch strips are placed under the stacks, and a few inches of space left between each stack for air circulation. In common storage, onions store better in slatted crates than in bags.

Varieties. These storage groups have been arranged:[250] *Very poor*—Italian Red. *Poor*—California Early Red, Crystal Wax, Yellow Bermuda, Grano. *Fair*—Sweet Spanish. *Good*—Red Wethersfield, Danvers, Early Yellow Globe, Southport, White Portugal, Ebenezer. *Very good*—Creole, Australian Brown.

Temperature. The best storage temperature is 31–32°F. The commonest form of decay is gray-mold rot which occurs at the top of the bulb, whence its name "neck rot." This fungus can develop to some extent even at 32°F., and so onions for storage should be carefully sorted to remove all diseased bulbs. Onions tolerate slight freezing but not alternate freezing and thawing. In storage the average freezing point of bulbs and sets is 30.1°F. Should they freeze, they should thaw slowly, with a minimum of handling, at about 40°F.

Yellow onions develop a deeper or darker yellow color at relatively high temperatures. A sudden change in storage from yellow to blotched brown or uniform brown, from red to deep greenish black, or from white to greenish yellow may be due to ammonia fumes from a leaking refrigeration system.

Humidity. A low humidity (60–75 percent) largely prevents growth of roots and checks spread of rots but increases the rate of softening and shriveling, whereas a high humidity has the reverse effect. Aids to maintenance of low humidity are an aboveground storage and closing of ventilators on cloudy or rainy days. High humidity is suitable for onions providing they are kept at 31–32°F. and condensation of moisture is avoided.

Shrinkage from sprouting, rotting, and so forth is commonly 7–15 percent under rather favorable storage conditions and is due largely to loss of water, sugars, and other products used in respiration.

Because of the odors which may be absorbed by other stored products, a separate storage room should be used for onions.

Carbohydrates. The reserve carbohydrates of onions are soluble and may comprise 65 percent of the dry matter. Sugars are the chief source of energy in respiration, and so this group of compounds shows the effect of unfavorable storage conditions. In storage from November 1 to February 15 in Massachusetts:[29] loss of total sugars was 0–8 percent; the percentage of loss was lowest for the coldest storage; and the largest percentage of reducing sugars was found in the coldest storage. An 8 percent loss of total sugars was equivalent to ½ pound of raw onions per 100 pounds.

Rest period. Varieties that have thick outer scales, cure well at the neck, and are hard and firm have the longest rest period. Some, like Australian Brown and Ebenezer, do not sprout for several months, even when placed under conditions favoring growth. The meristematic stem tip and young leaves are tightly enclosed by the surrounding scales which may act as membranes to retard the intake of oxygen and thereby inhibit growth. But in time they become more permeable and permit entrance of enough oxygen to start growth.

Sprouting. Preharvest foliage sprays of maleic hydrazide may be helpful in controlling the sprouting of onions in storage.[436] A solution of 1.5 pints of active ingredient in 75 gallons of water (a dilution of 2,500 ppm.), per acre, applied shortly before the tops are down greatly retards sprouting irrespective of storage temperatures.

Sets. Sets need about the same conditions as large onions and are best stored in shallow slat-bottom crates or trays not over 5 inches deep. Because of their small size, sets tend to pack closely in the crates, and so it is wise to allow good air circulation. (See Premature Seedstems.)

Marketing

Dry onions are usually marketed in 50-pound, open-mesh sacks. These have a coarse mesh through which the bulbs can be seen

readily, are attractive, and give good ventilation. Sometimes 5-, 10-, and 25-pound sacks are used.

Bunched green onions and shallots are shipped from Louisiana in a 4-bushel barrel, holding 20 dozen bunches, and in a 1⅓-bushel crate, holding 8 dozen bunches. A crate that holds 15 dozen bunches of small onions, or 10 dozen bunches of larger onions, is used in Washington.

Pungency and Odor

Mild onions are usually preferred for salads, seasoning, and cooking. Highly pungent ones are used by the manufacturers of sauces, canned soups, onion powder, and onion salt.

Onions owe their pungency to a volatile oil (allyl propyl disulfide), and may be divided into four groups: [304] (*a*) the mildest of all—imported bulbs of Red Italian, which, however, shows much higher potency when grown in America; (*b*) less mild—Early Grano, California Early Red, and Sweet Spanish; (*c*) rather strong—standard yellow onions; and (*d*) the most pungent—White Portugal, Australian Brown, and Ebenezer.

There is a steady increase in volatile sulfur until the plants near maturity. The peak is reached just before the tops begin to fall over. If the onions are left in the field longer the volatile sulfur content gradually decreases. The trend is the result of the growth cycle and not of the weather at the time of sampling. With individual plants, volatile sulfur continues to accumulate in the bulbs at all stages of growth. But during the maturation period the rate of synthesis is much smaller while the growth rate of the bulbs remains almost unchanged.

Onions grown at Davis, Calif., are more pungent than those grown from the same lot of seed at Winter Haven, Tex., near Washington, D. C., or at Amherst, Mass. Onions grown in north central Ohio are also more pungent than those at these three locations but milder than those grown in California.[249] Varietal differences in pungency are associated with moisture content of the bulbs; i.e., the most pungent varieties have the lowest percentage of moisture (highest percentage of dry matter). Pungency increases with increase in average growing temperature, with a decrease in soil moisture, and during several months in storage.

Hail Injury

A study was made in Texas[169] on the loss in yield due to removal of definite amounts of foliage at intervals of 1–6 weeks preceding harvest; i.e., (*a*) foliage was cut off near the base of the lowest blades (complete loss of foliage), and (*b*) foliage was removed at a point about one-third of the way up the plant from the base of the lowest leaves (half the foliage lost).

Yields of U. S. No. 1 jumbo and medium-sized onions were cut 76 percent by the complete removal of foliage 3–6 weeks before harvest. With the foliage removed 2 weeks before harvest the loss in yield in the same grade was 52 percent, and 1 week before harvest, only 20 percent. Losses in total yields paralleled those just given, but were smaller. Removal of half the foliage 2–6 weeks before harvest caused 44 percent loss in the yield of U. S. No. 1 jumbo and medium size, and a loss of 35 percent in total yield. Such injury only 1 week before harvest caused negligible loss.

Losses in yields of U. S. No. 1 jumbo and medium-sized onions as a result of foliage removal were chiefly due to the great reduction in total yield, rather than to increase of culls and boilers. The onions treated when they began to bulb, 5 weeks before harvest, suffered the most in yield. Actual hail damage usually leaves the foliage more torn and pounded than artificial cutting, and there is more danger of complications from decay diseases, especially if the hail is followed by several rainy days. Injury to the bulbs 1–2 weeks before harvest causes a much greater danger from decay. Injury to the bulbs requires a separate estimate of yield losses from the one based on foliage injury, but such a loss is relatively easy to estimate because the injury actually occurs to the marketable portion of the crop.

Insect and Disease Control

Onion maggot pupae, which resemble grains of rice, winter in the soil. In late spring flies with olive-green bodies and black heads and legs begin to appear. In 2 weeks they begin to lay their tiny, white elongate eggs, at the base of the onion seedlings. The eggs hatch in 1 week. The maggots migrate along the rows; one insect may kill 6–8 seedlings before reaching maturity. Con-

trol: Place the seed in a cheesecloth bag. Thoroughly moisten in a solution of ¼ pound white sugar to 1 quart water, or in water alone if the seed is sown at once. Whirl the bag until excess moisture is driven off. Weigh out calomel (to same weight as seed) into a nonmetal container. Stir the seed and poison for 5 minutes. The seed is then ready to sow. For sets or transplants spray with Bordeaux oil, or dust or spray with chlordane, when the plants are 1 inch high or when eggs are found at the base of the onions; repeat three times at weekly intervals.

Onion thrips are very small and yellow. They cause whitish blotches on the leaves and the tips to turn brown and die. Control is spraying or dusting with chlordane or DDT when the thrips appear and repeating two or three times at weekly intervals. Bunching onions should not be treated later than 3 weeks before harvesting.

A. Diseases primarily important in the field.[395]

1. Dark pustules, within the leaves or scales, which may later split open, exposing black powdery masses, chiefly on young seedlings: *Smut.*
2. Rapid death of young seedlings in circular patches: *Damping-off.*
3. Leaf tips pale green and yellowish, becoming covered with a violet furry growth, and finally collapsing; mostly in moist weather in mid-season or later: *Mildew.*
4. Black moldy growth on leaf tips or seedstems, often after mildew or purple blotch: *Leafmold.*
5. Large purple lesions, sometimes zoned, eventually girdling leaves and seedstems: *Purple blotch.*
6. Rapid dying-back from the tips of the leaves, accompanied by a rot starting at the base of the bulb: *Fusarium rot.*
7. As in A6 but round black bodies appear in the bulb: *White rot.*
8. Roots turning pink and dying; new roots attacked as they develop, marked stunting of plant: *Pink root.*
9. Orange-yellow pustules on leaves or seedstems: *Rust.*
10. Pronounced stunting and degrees of yellowing: *Yellow dwarf.*
11. Leaves sickly green; swellings on the roots: *Root-knot.*

B. Diseases primarily important in storage and transit.

1. Rot at the neck of bulb, progressing downward; tissue shrinking and collapsing, later a gray-brown mold and hard black kernels on the scales: *Neck rot.*
2. Soft watery rot at harvest time or later; foul odor: *Soft rot.*
3. Semi-watery rot from the base of the scale upward: *Fusarium rot.*
4. Black powdery masses on or between the scales; not in definite pustules: *Black mold.*
5. Superficial black spots made up of fine dots, but with no powdery

masses, shortly before harvest time on the outer scales, chiefly on white types: *Smudge.*

6. Semi-watery decay, first yellow, then wine red, and finally black, attacking the neck or wounds in the scales, which become papery: *Purple blotch.*

Smut-affected seedlings are stunted and may die slowly by drying out. The formaldehyde-drip method, or sets that are immune, should be used.

Neck rot is worst on white varieties. The bulb may become a dry mummy. White sets can be placed in shallow slatted crates in kilns where warm air (100–120°F.) is forced through them by a blower for several hours until the neck tissue is dry; thus the rot fungi can be checked.

Smudge persists in the soil and is worst on white onions. Thorough curing and protection from rain after harvest aid in reducing losses.

Pink root is disseminated on diseased green or bottom sets, on tools, and by drainage water. The Spanish type is less susceptible than the American type.

GARLIC

Garlic, a much maligned vegetable, is eaten daily, though usually unknowingly, by many thousands of persons, as a flavoring and seasoning in prepared food products such as soups, sausages, and pickles. It is also used to some extent in salads. Garlic salt is made from pulverized dehydrated cloves. The odor of garlic is strong, but the uses to which the crop is put in this country, and the esteem in which it is held by people of the Mediterranean races, indicate desirable qualities. The chief commercial areas are in California, Texas, Louisiana, and Arkansas.

Garlic produces a group of small bulbs or segments called cloves. These are covered with a thick whitish skin. Garlic is a perennial in mild regions but is grown as an annual in northern regions.

History

The history of garlic, like that of the onion, dates back to time immemorial. Middle Asia is the primary center of origin and the Mediterranean area the secondary center. The Israelites

wandering in the wilderness complained bitterly to Moses about the lack of garlic (see Onion).

Varieties

There are three types: (*a*) *Creole* (Early, Louisiana, White Mexican), (*b*) *Italian* (Late or Pink), and (*c*) *Tahiti*. Creole is earlier than Italian, has a flatter, broader leaf, a greener top, a shorter stem, fewer wrapper leaves, and larger cloves. It is a heavier yielder, but its keeping quality is somewhat inferior. Tahiti has the largest cloves, and they also are darkest.

Producing Garlic

Climatic Requirements

In California, garlic does best in areas where the summer and winter temperatures are moderated by ocean breezes. The crop is planted in late fall and harvested in June or July. In central California, where most of the crop is produced, the plants grow throughout the winter; although the top growth may not be extensive, a good root system is being developed. Summer temperatures do not injure the growing plants in these areas. But after digging, the bulb, particularly of Creole, is easily sunburned and so must be well protected.

In Ohio, spring-planted bulbs commonly do not grow large enough to compete with those from the South and West. Yields are often only 30 bushels and seldom over 100 bushels per acre. Excessive heat and unsuitable length of day may contribute to the failure of the crop to bulb properly. Fall planting seems essential for best results.

Propagation

Garlic is propagated from the small cloves or segments of large bulbs. Each large bulb contains about 10 small ones. All the cloves are planted, except the long slender ones in the center of the bulb. Bulbs with side growths should be discarded.

Soil and Fertilizer

Soil that is suitable for onions will usually produce good garlic. Heavy soils tend to prevent the equal expansion of the bulb, so

that irregular shapes and rough surfaces result. Heavy soils become dry and hard at harvest time, and while being pulled the bulbs are often badly broken and bruised. These injuries promote rots and poor storage quality. Garlic is seldom grown on light sandy soils as they lack sufficient moisture-holding

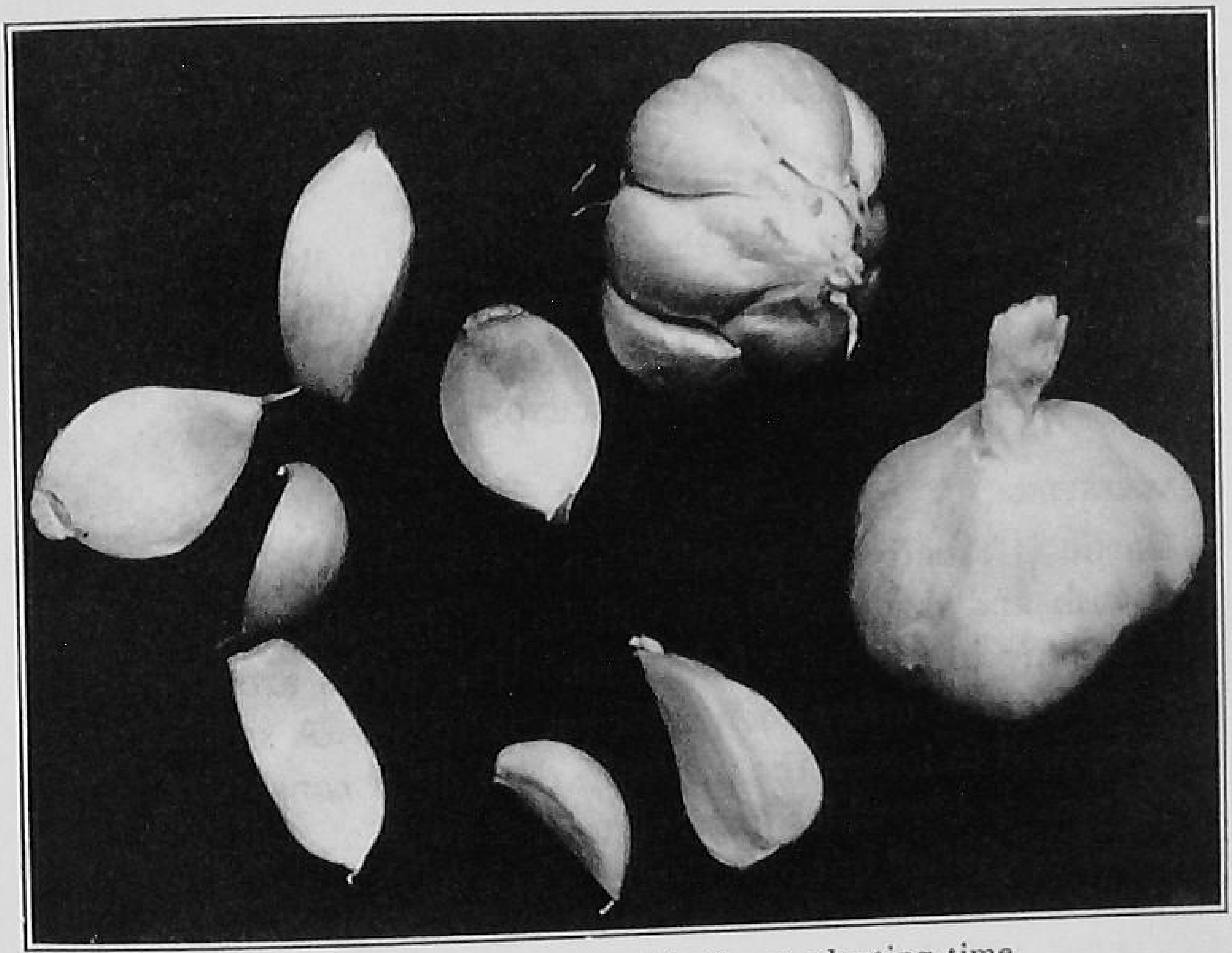

FIG. 34. Garlic cloves and bulbs at planting time.

capacity to mature the crop without irrigation. Wet soils tend to produce large, discolored bulbs which do not keep well.

PLANTING

Garlic is usually planted 3–6 inches apart and 1–2 inches deep in rows 18–24 inches apart. The cloves must not be so deep that the soil will check swelling of the bulb nor so shallow that they will wash out.

In Louisiana [382] the ridges are commonly 5–6 feet wide with 2–3 rows of garlic on each ridge. With about 150 cloves to the pound it takes about 235 pounds to plant an acre on ridges 2½ feet apart, with 6 inches between the plants. In southern Louisiana planting is done in October and November.

Tillage and Irrigation

When bulbs begin to form one should see that the soil does not interfere with their normal expansion, as may happen if the soil is packed around the base. Irrigated garlic often develops side shoots and stiff necks, and may not keep well. If the moisture is deficient during the growing season, development of the bulb is checked temporarily, and later irrigation causes the partly developed cloves to form tops.

Sprouting

When bulbs sprout, the sheath binding the stem bursts, and little stems or shoots develop. At harvest, such bulbs have a large collection of tops, and the cloves are not usually enclosed in a sheath, so that the crop is unsatisfactory.

Harvesting

Garlic is usually harvested when the tops turn brownish or yellowish and dry up. This will be in the fall in the North, but in May in Southern Louisiana. The bulbs are allowed to dry outdoors or under shelter for several days. A special cutter may be used to loosen the plants in the soil; it consists of a horizontal cutter bar which passes under 2 rows at a time. Then the garlic is pulled out of the soil.

Cleaning and Plaiting

When the bulbs are dry enough they are cleaned. The cleaning consists of removing the outer loose portions of the sheath and trimming off the roots close to the bulb. They may be handled like dry onions (loose garlic) or tied in bunches.

For plaited garlic the bulbs are braided by their tops into strings of 50 bulbs each (single strings). The tops are plaited together in such a way as to hold the bulbs on the outside. When two strings are joined, a double string of 100 bulbs is formed. When the bulbs are being trimmed and plaited, they may be sorted into three sizes. Each string should contain bulbs of uniform size. In Louisiana the yield is about 250 double strings per acre.

First-class garlic is clean and white, and without bulbs with the outer sheath broken. Sprouted garlic is usually unsalable

commercially, but factories that are not particular about having the cloves enclosed in a neat sheath may take it.

Curing and Storing

Garlic must be well cured before being stored. If not well cured, it is likely to heat if confined. Garlic is best stored under the conditions required for onions. The average freezing point in storage is 25.4°F.

Insect and Disease Control

The garlic is subject to the insects and diseases discussed under Onions.

GARDEN LEEK

The leek is a biennial that is grown as an annual for its long, blanched stems. It forms a thick, fleshy structure like a large green onion plant without a bulb and is attractive in appearance with its silvery base and green top. The leaves are flat, in contrast to the round ones of the onion. It is used, particularly by those of continental origin, in soups, in stews, creamed, and raw. Though all parts of the plant possess an offensive and pungent odor, it has a sweet flavor. The leek is started, like the onion, from seed, but it is usually sown in a trench, or otherwise handled, so that the plants can be more easily hilled up or blanched as growth proceeds. It is about as hardy as the multiplier onion.

History

The leek originated in the same areas as the onion and garlic. It has been cultivated and used for medicinal and culinary purposes since prehistoric times.

White and green, the hues of the leek, are the Cymric colors. On March 1, the Welsh wear them in celebration of St. David. In the British Museum a folio dating back to 1536 records that a leek had been presented to Princess Mary on St. David's Day as the national emblem of Wales.

Varieties

Carentan is probably as good as any. The leaves are thicker and darker green than those of *London Flag*. *Musselburg*

(Scotch Leek) forms a longer, thicker stem than London Flag (from which it was selected), with large but narrower leaves.

Producing Leeks

Transplanting Method of Growing Plants

For an early crop, and to secure the largest leeks, seed is sown in a greenhouse or hotbed in late winter and transplanted out-

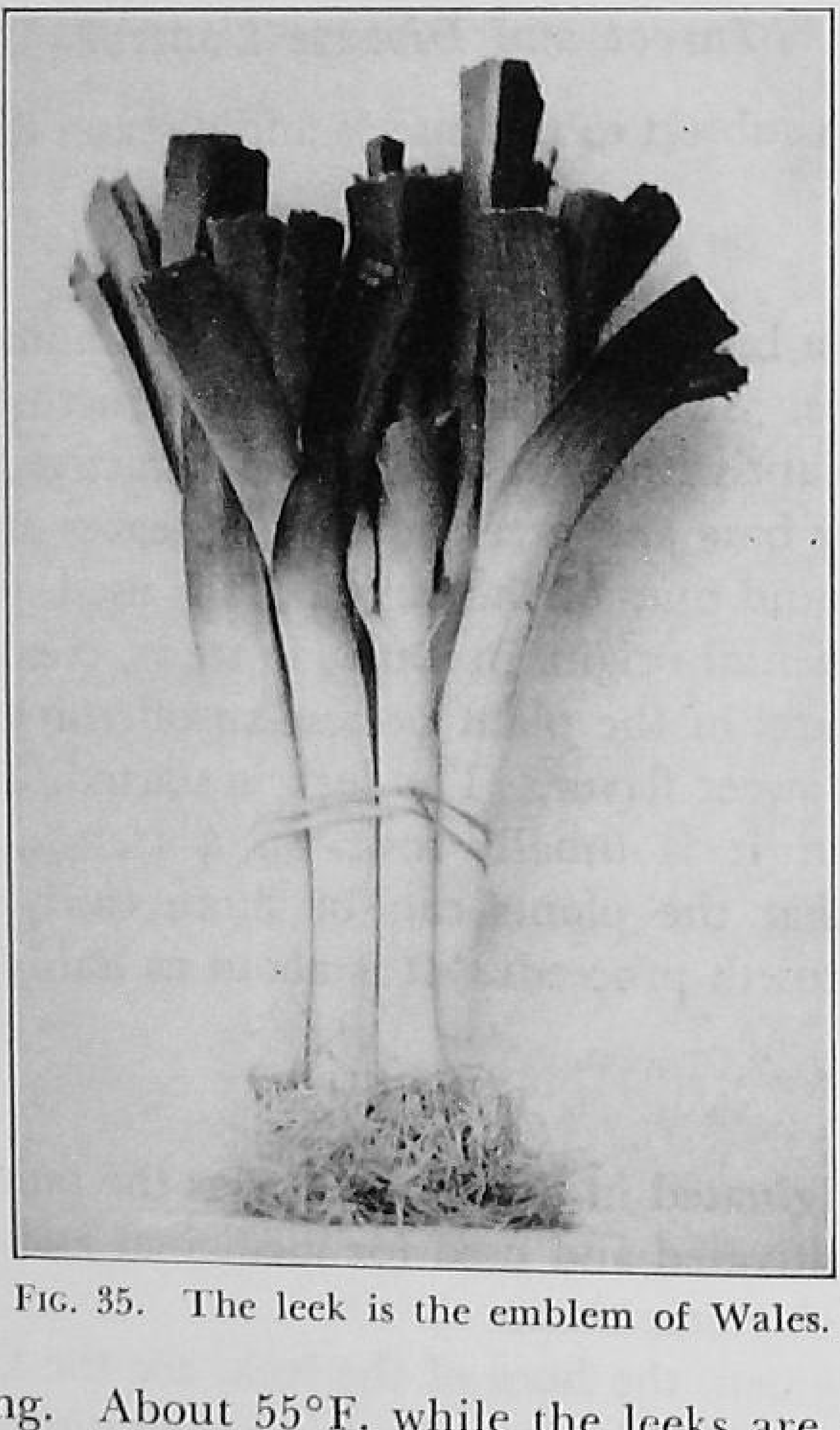

Fig. 35. The leek is the emblem of Wales.

doors in spring. About 55°F. while the leeks are under glass is desirable. When the seedlings are 1–2 inches high, they are pricked-out to boxes of richer soil, spaced 2½–3 inches apart, or individually in small pots for home gardens.

In a hotbed, the seed is sown in rows about 2–3 inches apart. When large enough, the seedlings are thinned to about 1 inch apart. Later, they are transferred to open ground. When the seedlings are as plump as straws, or at planting time, many growers cut the tops back about one half. Others prefer to keep

the tops intact and place emphasis on a ball of earth around the roots when transplanting. Setting the plants in a trench or furrow 4–5 inches deep facilitates blanching later. In level planting, it is wise to plant as deep as the base of the leaves and to close in carefully without undue pressure. Spacing is 6–8 inches apart in the row.

Seeding Directly in the Garden

Seeding directly outdoors is adapted to areas with a long growing season. It is desirable that the plant develop good size, and it needs a long season to do so. Hence, seeding is done as early in spring as is practicable.

Blanching

Blanching of the leaf-bases or edible portion is essential. Blanching with soil is begun after the plants have recovered from transplanting and is continued gradually as they grow, care being taken not to fill up the furrow or to bank up too early as the plants decay easily when young. The blanched portion should be at least 6 inches long.

Harvesting and Storage

Leeks are ready for use any time after they attain suitable size, but under favorable conditions they grow 1½ inches in diameter, with usable stalks 8–12 inches long. They are marketed in bunches like green onions. Good storage conditions for 1–3 months are 32°F. and 85–90 percent relative humidity. The average freezing point is 29.2°F.

Insect and Disease Control

Leeks are subject to the insects and diseases discussed under Onions.

7 · SALAD CROPS

LETTUCE

Lettuce, "the king of the salad plants," is grown in most home gardens and market gardens. It is one of the leading crops grown on muck land.

History

Cultivated lettuce (*Lactuca sativa*) probably originated in inner Asia Minor, the trans-Caucasus, Iran, and Turkistan. Lettuce has been known for over 2,000 years. Perhaps the height of its early popularity was reached when a great Roman patrician family adopted Lactucini as its name. All our types of lettuce were known in Europe before the Middle Ages.

In 1860, varieties like Tennis Ball, Malta, and Salamander were being grown in American gardens. Between 1860 and 1910, the following varieties appeared: Prize Head (1868), Big Boston (1870), Hanson (1875), Black Seeded Simpson (1880), Denver Market (1890), Grand Rapids (1890), Iceberg (1894), Mignonette (1895), New York (1896), White Boston (1902), Wayahead (1908), and New York 12 (1910).

In 1922, in the Imperial Valley in California, Dr. I. C. Jagger, U. S. Department of Agriculture, began lettuce breeding work. The pedigrees of the Imperial varieties are known but complicated.[195] They have descended through hybridization (in some cases involving White Charvigne and Big Boston) or selection or both from the variety New York or New York Special (a somewhat less variable selection).

In the 1940's, Whitaker of the U. S. Department of Agriculture and Lewis of Pennsylvania State College introduced a number of varieties that became widely grown in the East, e.g., Great Lakes, Premier Great Lakes, Pennlake, and Progress.

Classification and Varieties

A. Head lettuce.

1. Cabbage type. Broad leaves; round or flattened heads.
   (*a*) Crisphead varieties. Firm heads of crisp texture.
      (i) Plants wholly green: New York 12, Imperial 44, Imperial 456, Imperial 487, Imperial 515, Great Lakes, Pennlake, Premier Great Lakes, Progress.
      (ii) Plants tinged brownish, large part greenish: Iceberg.
      (iii) Plants brownish, only small part greenish: Mignonette.
   (*b*) Butterhead varieties. Soft, fairly solid heads; inner leaves oily, soft buttery, or greasy in texture; heart moderately tightly folded, blanching to a light golden or buttery yellow; plants even less resistant to heat than the crisphead varieties; maturing in a little less time than the crisphead types.
      (i) Plant wholly green.
         a. Large heads: White Boston, Deacon, Wayahead.
         b. Very small or miniature heads: Commodore Nutt, Tom Thumb.
      (ii) Plants tinged brownish, large part green: Big Boston, May King, White-Seeded Tennis Ball.
      (iii) Plants spotted brown: Bibb.
      (iv) Plants brownish, only small part greenish: Continuity.
   (*c*) Oakleaf varieties. Semi-loose heads: Oak Leaf, Bronze Beauty, Salad Bowl.
2. Cos or Romaine type. Long, narrow (spatulate) leaves; elongated, upright heads.
   (*a*) Large heads: Paris White, Dark Green, Red Romaine.
   (*b*) Small heads: Little Gem.

B. Leaf or bunching lettuce. Loose, nonhead-forming leaves.

1. Plants wholly green: Simpson's Curled, Early Curled Simpson, Black-Seeded Simpson, Grand Rapids, Boston Curled, Slobolt.
2. Plants brownish: Prize Head.

C. Stem type. No head; grown for the large, fleshy stem (peeled and eaten raw or cooked): Celtuce.

Most commercial field lettuce is of the crisphead, green, cabbage type. *New York No. 12* was the leader for some years. *Imperial 44* is somewhat more resistant to rot in the East. *Great Lakes* and *Imperial 456* were developed to tolerate summer conditions. *Premier Great Lakes* (All-America, 1949) is earlier, has smoother leaves, less "ribby," and more uniform in heading and maturity, on upland soil, than Great Lakes. *Pennlake* (All-America, 1949) is larger, firmer heading, and less "ribby" than Great Lakes. *Progress* (All-America, 1949) is richer green and thicker leaved than Imperial 44; the heads are more dense, more

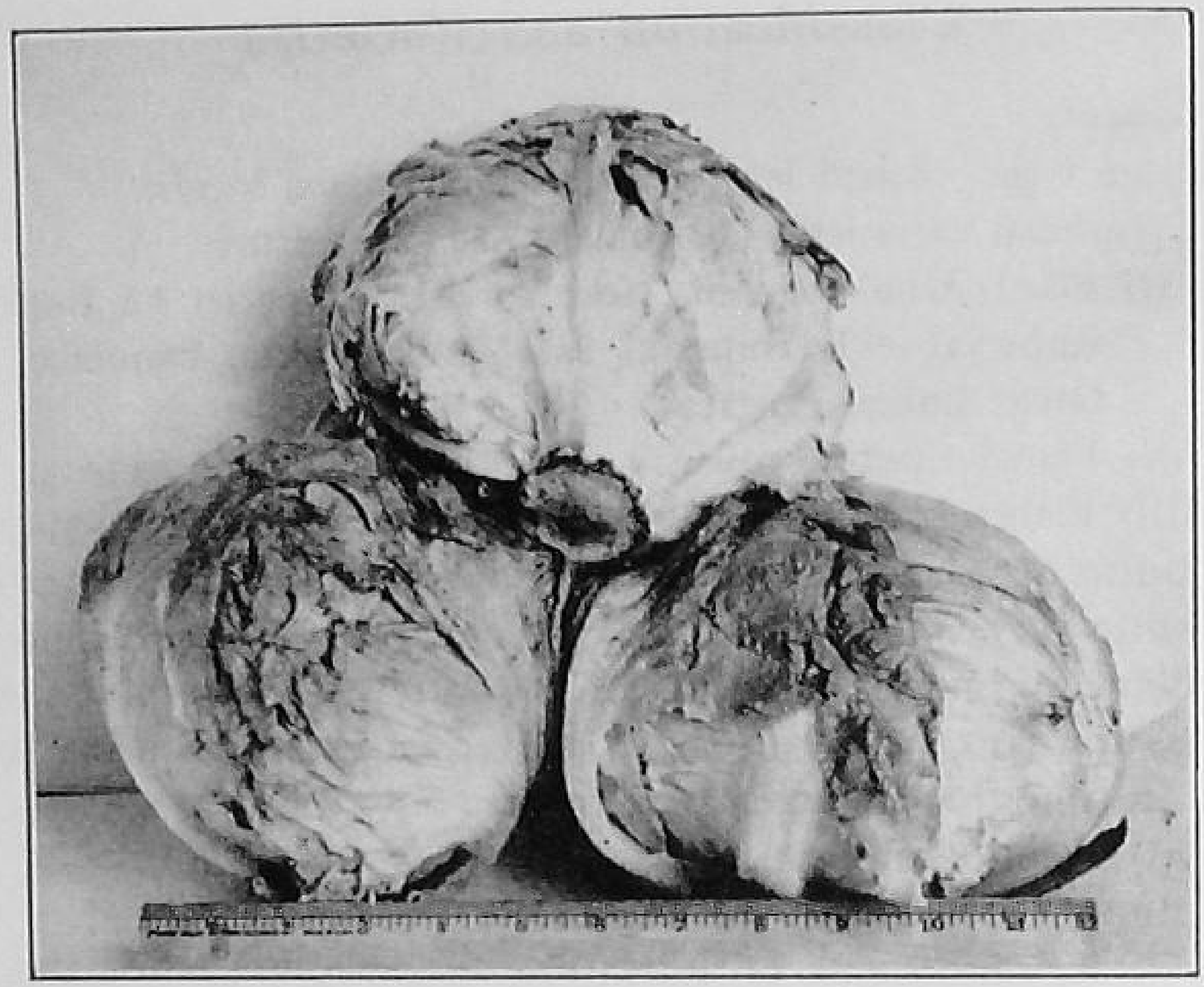

FIG. 36. New York 12 head lettuce. Long the leader, it has been superseded by improved strains more resistant to tipburn and other troubles.

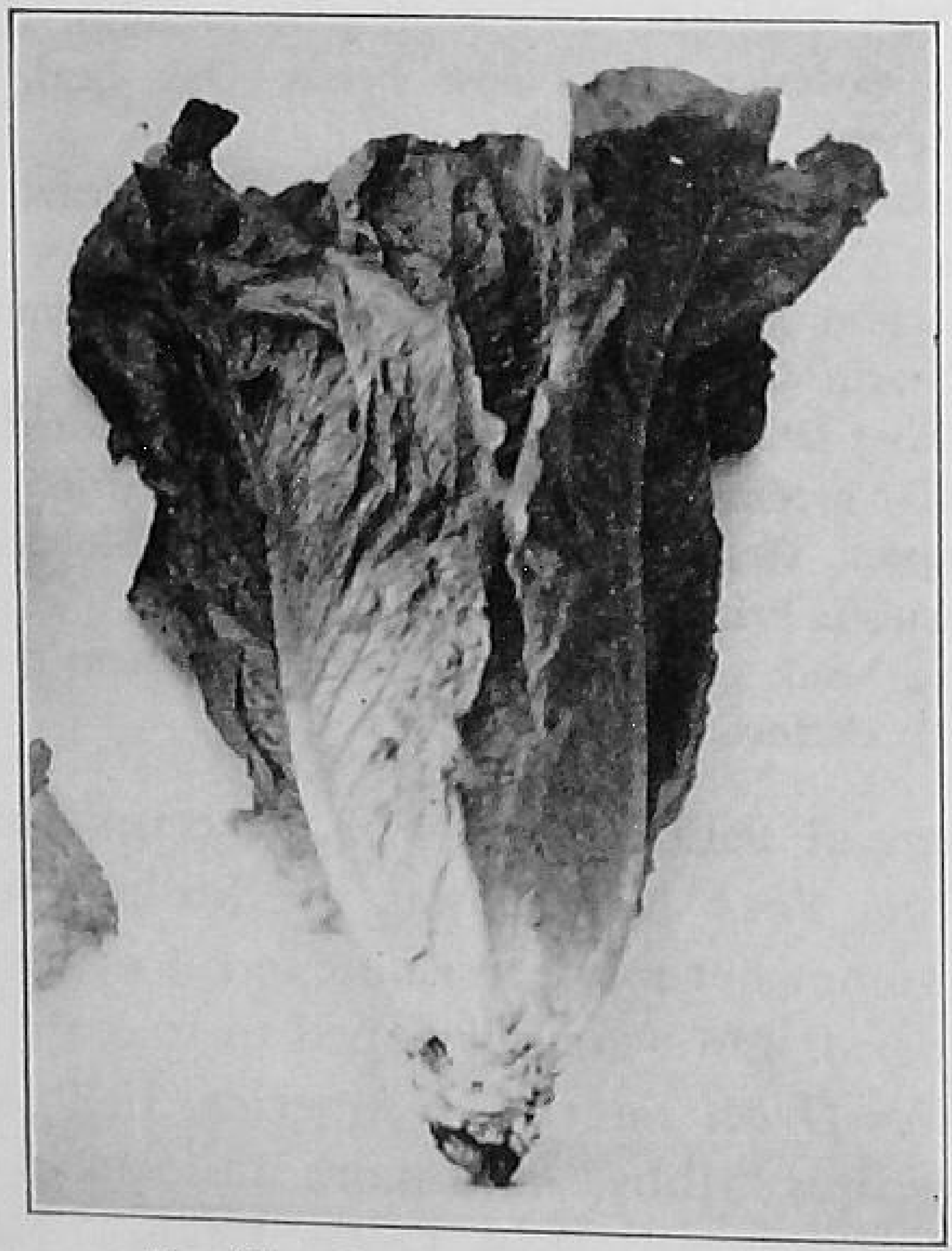

FIG. 37. Cos or romaine lettuce.

resistant to tipburn, and of higher quality. *Imperial 847* shows fair resistance to heat and rot in the South. *Imperial D* is a good cool-weather type and so is an important shipper on the Pacific Coast. *Imperial 615* is used in the Imperial Valley for midwinter shipment and elsewhere on the Pacific Coast for heading during cool weather.

In the trade, the New York strains shipped from the Pacific Coast are known as "Western Iceberg" or "Iceberg." However, there is a distinct Iceberg variety.

Butterhead varieties, e.g., *White Boston,* have largely been supplanted for market on this continent by crisphead varieties. *Salad Bowl,* a bunching type, has value for prepackaging.

The cos type, which is popular in the British Isles, is somewhat more tipburn resistant than other heading types, but it bolts quickly in dry periods and is not well adapted to shipping.

Plants of the leafy type do better than the head types under adverse conditions, for instance, in the heat of summer or as a greenhouse crop. It is commonly grown by home gardeners and is earlier, often by several weeks, than the heading types. The leaves are all exposed to the sun and are surpassed in taste by the tender, blanched leaves that develop in the center of head lettuce. A leading leaf lettuce for greenhouse culture is Grand Rapids, and for outdoors, Simpson. There are a number of strains of Grand Rapids, e.g., (*a*) Ohio strain, (*b*) Tipburn free strain, which is resistant to this disease in the greenhouse, (*c*) U. S. No. 1 strain, which is resistant to mildew, and (*d*) Slobolt strain which tends to remain in condition for a long period.

Plant Characteristics

Lettuce is an annual. One of its characteristics is a milky juice or latex.

Transplanting, when practiced, results in loss of the taproot. The root system is not very extensive, but it is a thick mass of roots, many of which are near the surface.

The leaves (see Classification) vary from light or yellowish to dark green; in some forms this is modified by a reddish or brown pigment, anthocyanin, that is a constant outdoor character of the variety.

In the stem type, e.g., Celtuce, the stems are very thick, reaching a diameter of 2 inches or more if grown on fertile soil during cool weather. In warm weather the stems are longer and less thick.

Producing Lettuce

Climatic and Weather Requirements

Lettuce is a cool-weather crop, and makes most of its growth below 70°F. High quality results only where the temperature of soil and air is moderately cool and uniform while the crop is maturing. This precludes the raising of the head types during hot summer days. Lettuce will not head if overtaken too soon by hot weather. High temperatures promote seedstems, cause a bitter taste in the leaves, and accelerate the development of tipburn and rot.

Head lettuce soon rots in hot, rainy, or humid weather. It needs a good amount of moisture in the soil, but not too much nor too little. Rain tends to increase tipburn rot, but the trouble is more serious if hot rather than cool weather accompanies the rain; hence heat rather than rain is the chief weather factor involved. Tipburn is due to excessive accumulation of respiratory products. It is seldom a problem during cool weather even though the humidity is high.

Hail sometimes occurs when the heads are approaching good cutting condition and results in serious loss. One effect is that the head becomes exposed, and if hot weather occurs subsequently rot soon develops.

Young lettuce, properly hardened, may withstand a temperature as low as 20°F., and so it is usually safe to seed or transplant comparatively early in the spring. Plants in hotbeds and coldframes should be protected against temperatures below 26°F. Wrapper leaves on mature heads are very susceptible to a light frost, and when so damaged the produce can only be marketed as No. 2 grade. With a fall or winter crop near maturity, sudden drops to 18–24°F., without previous hardening, may cause much injury to the heads, depending on the rapidity of the subsequent thaw. When a previous period of hardening weather has occurred there is less injury from the lower temperatures.

Premature Seedstems

Seedstems often develop before the plants are full grown and cause loss to the grower. High temperature is the chief factor involved. Bolting may occur during cool weather if the plants have been subjected while younger to a high temperature for an extended period.

Soil

Lettuce does best if the soil is rich in "plant food" and of a good friable texture. Very light soils low in organic matter are not suitable. Fluctuation of the moisture content is a drawback to very light mineral soils. Cool, well-drained muck produces good lettuce. The high organic content of muck gives it a high water-holding capacity and affords a uniform moisture supply.

The best soil reaction is *p*H 5.8–6.6. Yield is low at *p*H 5.0 or above *p*H 7.0. Although the plant is sensitive to high acidity, only on occasional sites where lettuce is grown is it necessary to apply lime. In fact, chlorosis develops under some conditions where the soil is brought to neutrality by liming.

Some lettuce diseases are controlled only by sanitary field conditions which consist in the removal of diseased plants and refuse, prompt and thorough plowing, and crop rotation. Crop rotation is very important on muck soil. Head lettuce following another crop of head lettuce in the same year or the preceding year may be small in size and late in forming hard heads. It may not be wise to grow head lettuce on land that produced celery the previous year. Growers usually fertilize celery heavily, and the fertilizer residue, combined with high temperatures at heading time, may promote tipburn, slime, and puffy heads.

Manure and Fertilizer

Lettuce, particularly the transplant, is a poor forager and has a rather small root system. Hence the surface soil should be well supplied with nutrients and humus. On mineral soils, organic matter is usually supplied in the form of barnyard or other types of manure or by plowing under green manure crops. Fresh manure, if used, should be turned under in time to decompose before planting.

Weeds, like vegetables, thrive on applications of manure. In fact, they grow so fast the manure is often blamed for infesting the garden with weed seeds. A study in New Hampshire[176] showed that cow and horse manure carried 25–35 weed seeds per greenhouse flat, when applied at the rate of 20 tons to an acre, whereas soil from weedy gardens had over 3,000 weed seeds per flat. The weeds from the manure were of all different kinds of grass, including witch grass, blue grass, and others, but no annual weed seeds were found.

No one fertilizer, or rate, can be specified for all sites. A soil test may be helpful in disclosing deficiencies of the major elements or an out-of-balance condition. Nitrogen can be applied in inorganic form, as in sulfate of ammonia, or in organic form, as in tankage, if it is so timed as to produce a good growth before the heading period (see later, Starting the Plants). Excessive nitrogen at heading time may result in large soft heads. Phosphate applied at seeding time outdoors sometimes gives firmer heads and earlier maturity. In general, the inorganic sources of plant nutrients give best results on nonmanured land.

Throughout the South Atlantic states, many soils are low in magnesium. Deficiency of magnesium, as indicated by a chlorotic condition of the leaves between the veins while the area adjacent to the veins remains green, is common in many fields along the South Atlantic seaboard.[379] It is wise to apply only dolomitic lime high in magnesium (16 percent or more of magnesium oxide) where evidence of a deficiency of this element is observed in lettuce plants. Where the *p*H is already high enough, it may be necessary, or at least advisable, to apply 25–50 pounds of magnesium sulfate to the land shortly before planting the lettuce.

On new muck soils and for at least the first 3 years, 100 pounds of copper sulfate and 40 pounds of borax may be needed per ton of fertilizer. Further minor element applications should be based on experience and evidence from experiments.

Starting the Plants

Seedbeds. In order to reduce the danger of crop failure due to unfavorably high temperature at heading time much of the head lettuce crop in the eastern and northern regions is started early in protected beds, or under glass, and transplanted to the field. Usually it takes 6–8 weeks to grow good plants for plant-

ing out. Crowding the seedlings too closely, thus preventing their drying readily after watering because of poor air circulation, is a frequent cause of damping-off.

A 50-sash frame (3 × 6 foot sash) and ¼ pound of seed should provide plants to set an acre or more. In the South Atlantic states most of the plants for transplanting are grown in beds with only a covering of thin muslin. They are protected from prevailing winds if a site on the sunny side of a woods or thicket is selected.

Soil temperatures may be so low for some time after setting in the field that the plants fail to obtain adequate nitrogen, become yellowish green, and are stunted. The grower can help the plants through this period by applying nitrogen, e.g., nitrate of soda or sulfate of ammonia about ½ pound per 100 square feet of bed, about a week before removing them from the beds. If the weather makes it necessary to hold the plants in the bed for several days after applying the nitrogen, they may become too succulent and suffer from crowding. Therefore only as much of the beds should be treated at one time as will be transplanted to the field within 7–10 days.

Hardening is promoted by exposing plants gradually to cooler conditions, by withholding water, or by both. Thoroughly soaking the soil in which the plants are grown, just before they are set in the field, encourages success in transplanting.

Direct seeding. Nearly all lettuce produced in the West and much of that in the East is grown from seed sown in the field with mechanical seeders. Two pounds of seed per acre are commonly sown, but under favorable conditions 1 pound may suffice. The lighter rate of seeding saves much labor in blocking and thinning.

Wide beds of 4–6 rows were formerly used in the East for growing the Boston butterhead type. With the shift to the New York crisphead type, the system of planting has mostly changed to either the single- or the 2-row bed. In some areas the single rows are planted on ridges of varying heights. Ridging is desirable where heavy rains occur during the growing season and where the soil is such that it does not dry quickly under the plants after rains. Some of the loss due to decay of the lower leaves may be avoided by growing the crop on narrow ridges. Ridging is not desirable on well-drained land or on light soils,

as it may cause the crop to suffer more during periods of limited moisture than it would under flat culture.

The 2-row bed is the most widely used system in the large districts of California, Arizona, and other western states.

Depth and Time of Seeding and Transplanting Outdoors

The seed, being small, should be sown shallow, but deep enough to contact moisture. If enough moisture for germination is assured, ¼ inch deep suffices. Mechanical seeders must be properly adjusted to drop the seed regularly, accurately, and at the proper depth.

Where the crop is grown under irrigation by the furrow method the water should be applied in advance so as to allow the soil to settle before seeding. In nonirrigated areas it is better to seed after a rain rather than just before.

Some varieties, e.g., Progress, germinate better than others, e.g., Great Lakes, at high soil temperatures (80–85°F.).

In California and Arizona, known differences in varietal response to weather have led to a well-established schedule of seeding dates (see Table 2). That is, the different varieties are seeded on such dates that they will develop during the seasonal conditions to which they are best adapted. The lack of adapted varieties and the limited growing season have so far prevented such a well-organized schedule for the East.

Hardened plants may be set outdoors as soon as danger of hard freezes is over. Transplants, especially if set on a sunny day, wilt considerably but recover in the cool of night. Deep planting results in more elongated heads than is normal.

Spacing

Crowding is a common cause of poor heading. Also, loss from disease may be much greater where too close planting causes poor air circulation around the plants.

On eastern muck land the usual spacing is 14–16 inches apart in rows 16–18 inches apart. In the western irrigated sections, where the crop is grown on 2-row beds, the usual spacing is 12 inches between rows on 22-inch beds with 18 inches between the beds, or a total of 40 inches from center to center of the beds. The top of the bed is 6 inches above furrow level. Where the

TABLE 2

SEEDING DATES FOR LETTUCE IN CALIFORNIA AND ARIZONA [379]

District and Variety	*Seeding Dates*	*Days to Maturity*
Imperial Valley, Calif.		
Great Lakes	Sept. 15 to 25	85–95
Imperial 152	Sept. 15 to 25	85–95
Imperial 615	Sept. 25 to Nov. 1	100–105
Imperial 17	Oct. 1 to 10	115–120
Salinas-Watsonville, Calif.		
Imperial 615	Nov. 1 to Jan. 21	100–145
Great Lakes	Feb. 1 to June 30	90–105
Imperial 847	Apr. 1 to June 30	65–85
Imperial 44	July 1 to Aug. 1	65–85
Imperial D	Aug. 1 to 20	90–100
Yuma, Ariz.		
Great Lakes	Sept. 1 to 15	85–95
Imperial 44	Sept. 10 to 25	85–95
Imperial 847	Sept. 15 to 30	85–95
Imperial 615	Sept. 20 to Nov. 15	100–105
Imperial 101	Oct. 1 to 20	100–105
Salt River Valley, Ariz.		
Imperial 44	Aug. 27 to Sept. 10	80–95
Imperial 152	Sept. 20 to Nov. 10	95–120
Imperial 615	Sept. 8 to 15	90–95
Great Lakes	Aug. 20 to Sept. 1	80–85
	Nov. 10 to Jan. 10	90–120

wide-bed system is still used, 6 rows are planted on a 6- to 7-foot bed with a 12- to 15-inch space between beds.

Blocking and Thinning

The first thinning of seed lettuce is done about 10–14 days after seeding (or when 2–3 true leaves have formed), the plants being blocked out with a hoe to clusters 8–15 inches apart. Then, 2–3 days later, the clusters are thinned by hand to a single plant.

Cultivation

Weeds must be kept out, and the soil surface must not be allowed to crack or form a hard crust. Otherwise, little or nothing is gained by continuing cultivation, and, in fact, it may cause

injury by bringing moist soil from below to the surface where it will dry out and by breaking the feeding roots. Some root pruning in cultivation may help check too rapid a growth caused by abundant moisture and favorable temperature where the soil fertility is high. This should be done only when it seems certain that the crop will be lost unless the growth rate is checked.

Irrigation

Most lettuce in the West is grown under irrigation. In the East, even with irrigation, the grower does not have as complete control of the soil moisture, because of heavier and more frequent rains. Heavy rains after the heads begin to form may cause great loss by upsetting the growth rate, especially on fertile soil high in available nitrogen or where the crop has been growing with somewhat below optimum moisture. A sudden increase in soil moisture with the resulting rapid growth after the heads have begun to form may interfere with the normal folding of the leaves, thereby precluding solid heads. An increase in the space between the bases of the leaves after they have begun to tighten over the head may result in large puffy heads. Only when very favorable temperature and moisture conditions prevail for several days after such a loosening of the leaves can firm heads develop.

In California,[390] three irrigations, the first to germinate the seed, the second at the time of thinning, and the third, 30 days later, will usually produce a crop without losses in yield or quality. A total of about 14 inches is ample irrigation water to produce a summer or fall crop.

Flooding is undesirable as the water would touch the plants. Furrow irrigations 5–6 days apart on sandy soil and weekly on heavy soil are good in warm weather. Water applied near the cutting period may cause heads to split. The water should soak the soil in the root zones, as indicated by moisture coming to the surface near the plants and between the furrows. In single-row plantings, water may be applied in every furrow, or in alternate furrows; in double-beds, no furrow should be missed. Under any system the chief factor is to maintain a uniform soil moisture. Soils low in water-retaining ability and subject to wide fluctuations in moisture, during periods of dry, hot weather, promote tipburn, loose puffy heads, and a bitter flavor.

In eastern or humid regions lettuce needs 5–8 inches of rain or its equivalent in irrigation for the spring crop, the amount depending somewhat upon the soil type and the prevalence of dull weather and of winds. The ordinary overhead or spray system distributes about 60 gallons of water per minute over an acre, thus requiring about 4 hours of watering to apply over the entire surface ½ inch of water, or enough to fairly saturate the soil. When water is applied from a sprinkling system in warm weather, early morning, while the plants are cool and before they wilt, is the best time. Great loss from tipburn and slime (soft rots) may result from careless irrigation of nearly ready heads by a sprinkler in the heat of the day.

Applying nitrogen (anhydrous ammonia) in the irrigation water is a commercial practice in some areas.

Harvesting

Leaf lettuce. When grown for market, leaf lettuce is usually allowed to develop to full size, though it is often cut soon after it is half grown if the demand is good. If left uncut too long it becomes bitter.

Head lettuce. Head lettuce is harvested when the heads are well formed, of good size, and solid. It is usually cut just above the ground, but in some shipping areas the cutting is done slightly below the soil surface. Heads that show seedstems, that have burst, or that have slimy tipburn are worthless.

It is best not to cut lettuce immediately after a rain, while dew is on it, or if it is frozen (fall crop). When the plants are full of water the leaves are crisp, brittle, and easily broken in handling. Also, excess water in the leaves encourages rot if the heads are held for some time. If the heads must be cut under these conditions they should be cut carefully and turned butt end up for a short time to permit the outer leaves to wilt slightly; then the heads can be handled with less damage to the wrapper leaves. At least 3 healthy wrapper leaves should remain to protect the heads in marketing.

Containers

Western lettuce is mostly shipped in the Los Angeles crate which holds 4–6 dozen heads. The crates are usually lined with heavy paper. The heads are packed in layers with the stems

upward. Western shippers have adopted a crate 14½ inches high, 18¼ inches wide, and 20½ inches long.

Precooling lettuce when the loads arrive at the packing shed is helpful in handling for shipment. If lettuce is packed before the field heat is removed there is a heavy wastage of ice in transit and also danger of shrinkage from rots, but package icing helps curb evaporation. Enough lettuce and ice are put into the crates to cause about 1-inch bulge at both top and bottom when the lid is brought down for nailing in the press.

Eastern lettuce commonly is packed in two layers, usually without package ice, in a crate measuring 9 × 17 × 22 inches (inside).

STORAGE

Lettuce, if in good condition, can be kept 2–3 weeks at 32°F. and 90–95 percent relative humidity. Stored lettuce must be inspected frequently for slimy rot. The average freezing point is 31.2°F.

Insect and Disease Control

For *cabbage worm* injury and control, see Cabbage. For *cutworm* control, see under Bait and DDT in Chapter 15.

The *six-spotted leafhopper* does little damage but transmits a virus, *lettuce yellows,* which causes yellowing, curling, and failure in heading. For control, see Carrots.

Watery soft rot starts at the ground line, progresses up the stem, and later causes a sudden collapse or "drop." It also causes damping-off of seedlings and an odorless soft rot in storage or transit. The tissue becomes watery and the liquid released leaks away readily. Controls are: sterilizing the seedbed, good spacing, burning infected plants, rotating the crop (avoiding cabbage or celery), and ridging the soil about the plants slightly to prevent water standing at the stems.

Tipburn is a high-temperature nonparasitic disease. Small dead spots develop near the margin of the upper, more tender, exposed leaves and prevent the passage of water to the edges of the leaf; the portion outside the spots becomes wilted and yellow and soon dies, leaving a dead, brown strip around the edge of the leaf. Secondary decay then results. Control is to plant varieties better able to withstand the conditions that cause the disease, or to have the crop mature in cool weather.

Slimy soft rot or gray mold is caused by *Botrytis* and various bacteria. Control is to avoid tipburn. *Bottom rot* decay of the head begins in the lower part. It is favored by warm, humid weather. Cultivate only when dry, and, as for the control of *drop,* practice spacing the plants well apart. *Damping-off* is reduced by seed treatment (see Table 5).

Big vein usually requires 4–6 weeks from the time the seed is sown or plants are set in diseased soil for symptoms to show. Then the chlorophyll disappears from the leaf tissues adjacent to the large veins and in extreme cases there is a swelling of the larger veins in the petioles and midribs. The affected leaves become brittle and are easily broken; normal growth and heading is disrupted. Root aphids may carry the virus.

Mosaic of lettuce is seed borne and is spread by aphids. A mottled appearance resulting from different densities of green pigment and deformed leaves are characteristic symptoms. Eliminating affected seedlings helps check spread of this disease.

CELERY

Celery is more popular in the United States and Canada than in any other country. The leafstalk or petiole is commonly eaten fresh. It is one of the main crops eaten without cooking. It is also used in salads, in soups, in sauce, in purée, fried, spiced, and as a relish with cheese.

Celery needs a long growing season, and so transplanting is commonly practiced. Prospective growers of celery should know of its high need for a well-distributed supply of moisture, its lack of tolerance of cool temperature in early stages which results in premature seedstems (though at other times it thrives best in cool weather), and a number of other important, and often limiting, factors.

History

Celery, which is referred to as *selinon* in Homer's *Odyssey* about 850 B.C., originated in the Mediterranean area. Its development as a garden plant began among the gardeners of the lowlands of Italy and spread to France and England. By selection, the wild plant, long considered poisonous, has been transformed into a crisp, sweet, appetizing, and wholesome food. The original celery had hollow leafstalks.

Commercial celery production began in the United States in 1884–1885 with the introduction of early, self-blanching varieties. The draining of the peat marshes around the Great Lakes greatly

FIG. 38. *Left,* golden, early, or summer celery. *Right,* green, late, or winter celery.

contributed to the development of commercial production. In the 1890's commercial production was begun in California and Florida. The late type is now the leader.

Classification of Types and Varieties

A. Golden, early, or summer celery. Comparatively light-green or yellow-green color; easily blanched; early.

1. *Golden Self-Blanching type.* Plants with medium-sized hearts which grow up rapidly after blanching has started; total height commonly 1½–2 feet and stalk length 8–11 inches to the first branches; leaves yellowish green; stalks somewhat stringy, and if grown rapidly quick to wilt in marketing; readily blanched to a creamy-yellow color; quality only fair.
   - (*a*) Tall strains: Tall Golden Self-Blanching (Improved Old Golden, Tall French, Tall Strain, Vilmorin Improved), Florida Golden.
   - (*b*) Intermediate strains: Supreme Golden.
   - (*c*) Dwarf strains: Golden Detroit, Dwarf Golden Self-Blanching.

2. *Golden Plume type.* Usually more vigorous, somewhat more erect, and with a capacity to develop a heavier heart in a shorter length of time than strains of the Golden Self-Blanching type; strains not as tall as the taller strains of the preceding type; blanched easily to a golden-yellow color; quality only fair; somewhat resistant to blight; fairly difficult to keep in storage.
   (*a*) Tall strains: Golden Phenomenal, Tall Golden Plume, Michigan Golden.
   (*b*) Intermediate strains: Golden Prize, Golden Treasure.
   (*c*) Dwarf strains: Wonderful, White Plume, Golden Plume, Nonbolting Golden Plume.

B. Green, late, or winter celery. Matures later, heavier, and of better quality than the golden or summer type; can be stored longer than the self-blanching varieties.

1. *Easy blanching type.* Plants somewhat shorter than Golden Self-Blanching, less erect, more vigorous, darker-leaved, slower to blanch, and easier to keep; leaves very green, glossy; stalks numerous, thick, rather brittle; intermediate between golden and dark-green celery in blanching characteristics; medium early, a little later than Golden Self-Blanching. This type can be classified as "green" celery with moderate blanching, yet with additional blanching it can be marketed in competition with the self-blanching and plume types: Easy Blanching, Fullheart, Crispheart, Sweetheart, Earligreen.
2. *Dark-green type.* Late; leaves rich dark green; usually not blanched when sold directly from the field. This type is very popular with consumers; sometimes partially blanched in the field. If placed in storage or banked with soil a certain amount of blanching occurs. Usually about 16–20 inches tall, with stalks about 5–8 inches to the first branches; stalks large, round edged, thick, and almost free from ribbing; heart heavy: Giant Pascal, Utah (Salt Lake), Utah 15, Utah 99, Tall Utah 10B, Fordhook, Epicure, Summer Pascal.

C. Intermediate class. Different from the others in combining the color of the golden or summer type with the round stalks of the later type; not commercially suitable for storage.

1. *Summer Pascal or Fordhook type:* Summer Pascal, Fordhook, Michigan State Green-Gold, Emperor.
2. *Golden Pascal type.* Golden Pascal, Cornell 6, 19, and 619 (6 × 19).

Plant Characteristics

Roots

Transplanting destroys the taproot, but lateral roots grow out in all directions, and these are covered with fine roots. The fibrous system is comprised of many adventitious roots that arise at the base of the plant. The root system chiefly occupies the upper 6 inches of soil, many of the roots being within 2–3 inches

of the surface and a few penetrating 2 feet deep. Most roots are within a radius of 6 inches of the plant. Celery is a poor forager for moisture and nutrients.

QUALITY

Differences in quality, aside from hereditary ones (as between varieties), are influenced by external factors, such as soil moisture, plant food, rate of growth, light, temperature, and pests. Flavor

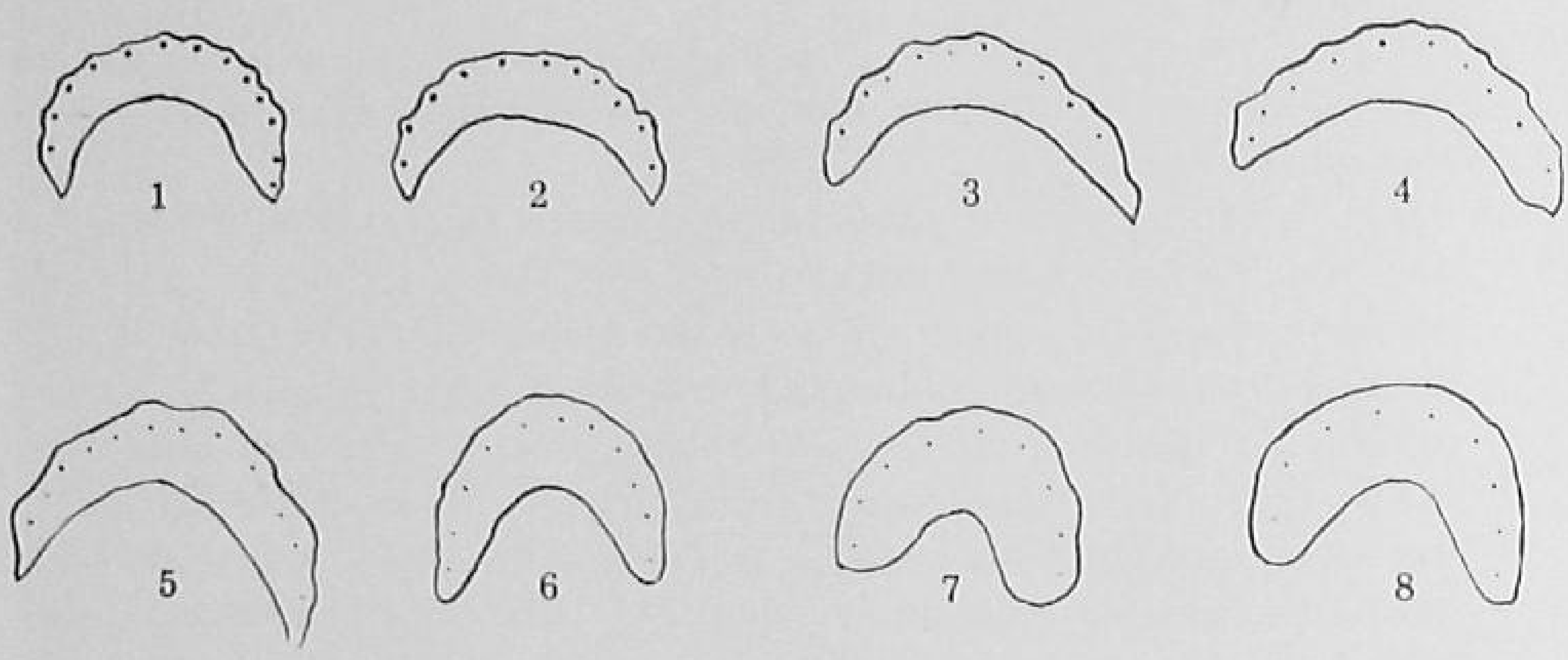

FIG. 39. Cross section of celery stems. 1, Supreme Golden; 2, Golden Detroit; 3, Golden Plume 4162; 4, Golden Plume; 5, Sweetheart; 6, Utah (Salt Lake); 7, Summer Pascal; 8, Cornell 19.

may be associated with chlorophyll content in the stalks. Lack of crispness may be the result of high temperature, too much or too little moisture, nitrogen deficiency, or excessive retardation or acceleration of the growth rate.

STRINGINESS

Both the collenchyma strands and the larger vascular bundles constitute the "celery strings." The xylem, which is lignified, contributes somewhat to stringiness, and the bundle cap also adds to the toughness. The greater resistance to breaking shown by the collenchyma strands is not due to larger strands, for in many varieties they are smaller than the entire vascular bundle, sometimes even being thinner than the bundle cap alone. Old collenchyma strands are tougher than younger ones, owing to an increase in thickness of cell walls.

PITHINESS

Pithiness is a condition in which the stalks are hollow and is correlated with a breaking down of the large, thin-walled parenchyma cells which leaves open spaces through the center of the stalk. The breaking down occurs as a splitting apart of the cell walls or of the cells along the line of the middle lamellae. Pithiness has been ascribed to growth checks, seed from pithy plants, too rapid growth, and too rapid growth after a growth

FIG. 40. Stringy (*left*) and pithy (*right*) celery stalks.

check. If the crop is severely stunted in late summer by drought and then watered heavily, pithiness develops. Severe injury by late blight and by insect feeding also may promote pithy plants.

There are two types of pithiness. One is present from the young seedling stage onward and is due to a genetic factor. Because pithiness is dominant, a few plants in a seed field are a ready source of contamination. Since "solid-petiole" is recessive, this pithiness may be eliminated from seedstocks by destroying the petioles of pithy mother plants so that they will not set seed. The other type appears in the outer petioles first and proceeds inwards towards the heart as aging progresses.

In the field, pithiness develops rapidly after the plants culminate their growth, but in storage it progresses more slowly because of differences in temperature. Since pithiness may be attributed to death of certain parenchyma cells in the center of the petiole followed by the loss of their constituent water and

subsequent drying out, respirable materials are involved. Also, pithiness is preceded by changes in osmotic concentration associated with translocation of sugars from the outer to the inner petioles. The crown is an intermediary point in the translocation.

Storage conditions may affect crispness, especially insufficient moisture and too high temperature, which result in overrapid maturation and pithiness.

Producing Celery

Seeding and Growing the Plants

A common mistake is failure to allow time enough for growing the seedling plants. The seeds are small and germinate slowly. The young seedlings need special attention.

Time of seeding. The seed for the early crop is sown in flats or in a seedbed, in a greenhouse or hotbed, often in sash houses with ground beds of muck. If the plants are not to be transplanted before being set in the field, 8–10 weeks are sufficient in most cases between seeding and planting. If the plants are transplanted once before being set out, 10–12 weeks' time should be allowed. Plants for the late crop in the North and for southern crops are usually grown in open beds.

Sprouting the seed. The seed is sown about $\frac{1}{16}$ inch deep. At 59–68°F. the seedlings emerge through the soil in about 2 weeks.

After the seed is sown it may be covered with burlap bags to hold the moisture in the surface and prevent washing out in watering. Weeds germinate before the celery seed, and they push up through the moist burlap. When the celery seedlings begin to show, the burlap is removed, taking with it thousands of weeds. Then the beds are shaded for a few days. (See Weed Killers, Chapter 15.)

The following plan [373] reduces the pre-emergence period and facilitates growing celery by direct seeding. In California, plot trials were supplemented by field sowings of 50–100 acres for 3 years by a grower who obtained good stands at relatively low costs. The seed is pretreated by soaking 16 hours with several changes of water, holding in 1 percent solution of sodium hypochlorite for 2 hours, rinsing, drying in light at room temperature, and centrifuging to water content of about 100 percent of the dry seed weight.

The moist seed is transferred to a dark place of high humidity and 48°F. for 16 hours and 70°F. for 8 hours daily. When sown at the end of 8½ days, about 10 percent of the seeds may have started to sprout.

Rate of seeding. There are some 75,000 celery seeds in an ounce, but one may not get more than 10,000 plants from this quantity because of the losses from poor germination, damping-off, culling of weak plants, and other reasons. About 2 ounces

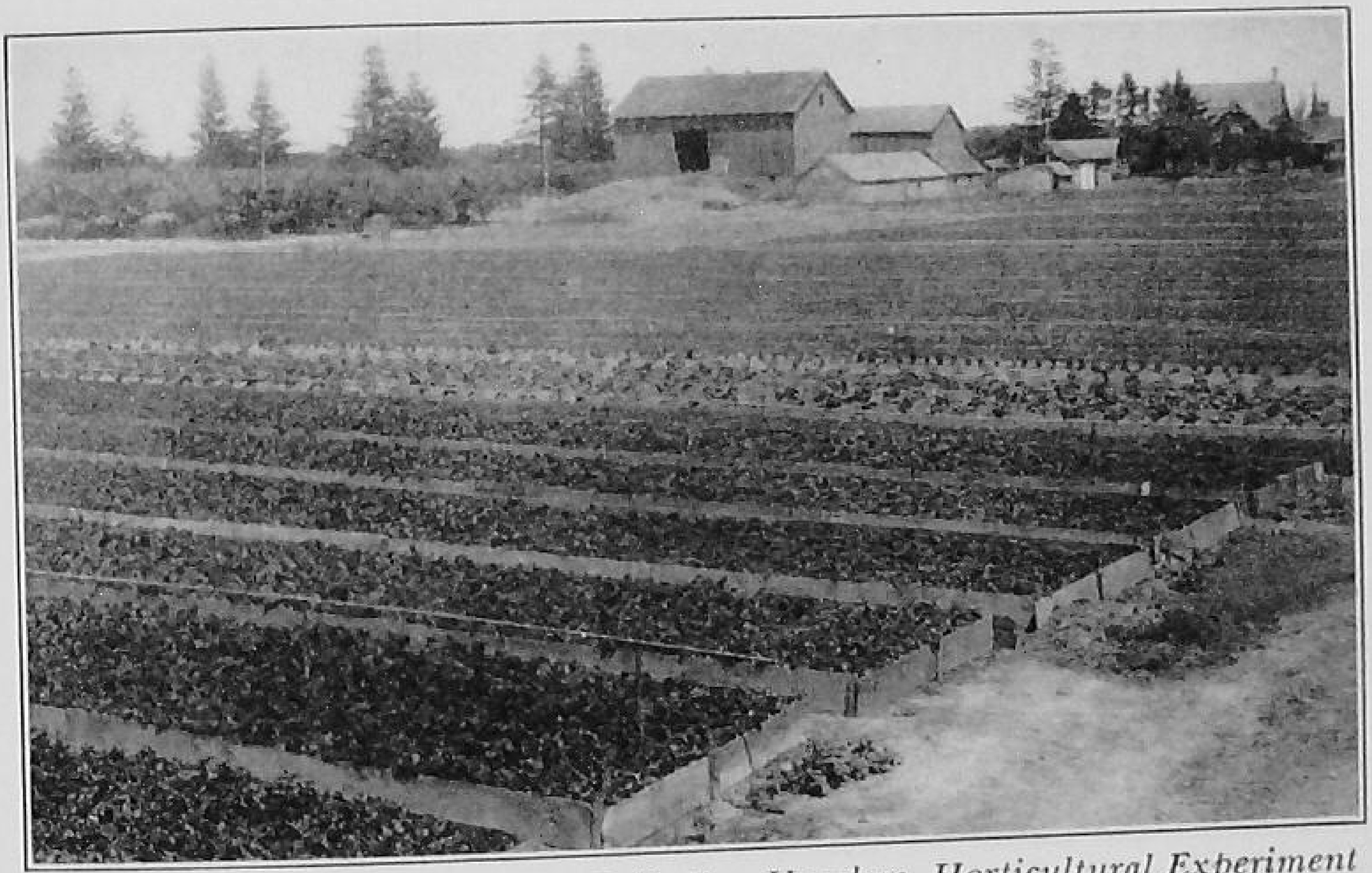

Fig. 41. Celery beds. (*Courtesy J. R. Van Haarlem, Horticultural Experiment Station, Vineland, Ont.*)

of seed are enough for an acre, planted 6 inches apart in single rows 3 feet apart. The seed is sown thinly to facilitate pricking-out or transplanting and to encourage stocky plants. One plan is to sow a level teaspoonful to 6 feet of row, if the crop is seeded in a hotbed. In outdoor seedbeds, row seeding, 4–12 inches apart, at the rate of 25–28 seeds per inch, is preferable to broad-casting. This method allows for cultivation and "furrow" watering and can reduce damping-off. It is often difficult to avoid spread of damping-off with broadcast seeding.

Pricking-out and thinning. With seed sown in flats, the seedlings are pricked-out 4–5 weeks after seeding, so that they stand 1½–2 inches apart in other flats. Thinning in the seedbed is done by hand. Those removed may be sorted and transplanted when ½–1 inch high, into other rows, or into beds, if they are

not discarded. Thinning in the seedbed is seldom practiced commercially on muck.

TRIMMING. When the plants are about 3 inches high, the tops may be trimmed to let sunlight reach the soil, keep the surface dry, and reduce damping-off losses. The value of trimming is uncertain. Some claim it produces stockier plants that start growth more readily. It undoubtedly checks growth and possibly

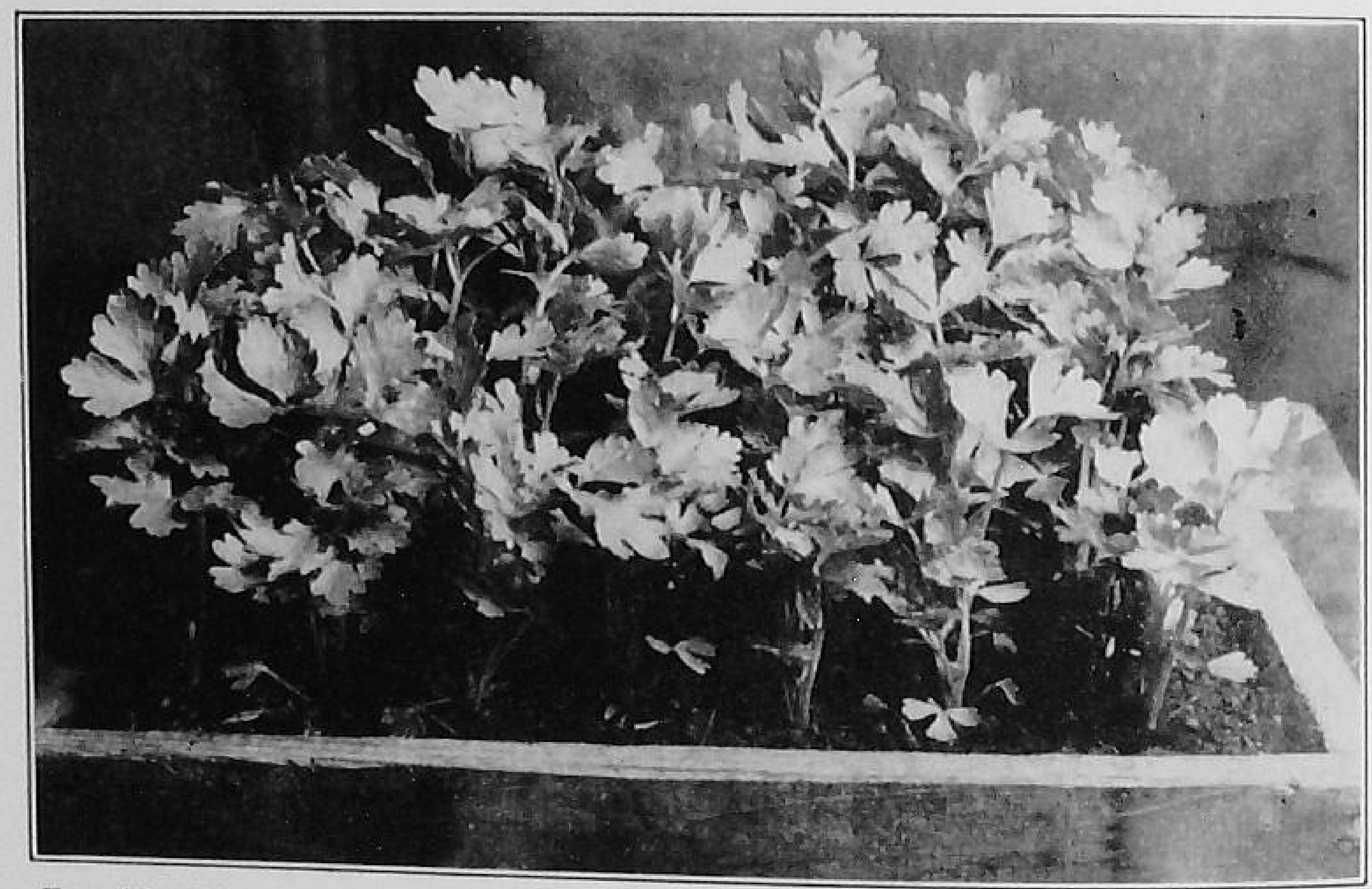

FIG. 42. Exposure of celery seedlings to cold at this stage results in bolting to seed in the garden.

allows better air circulation, which in turn may avoid some loss from damping-off. But if the seed is sown at the right time there should be no need for trimming, although seeding 2 weeks too early may necessitate some such practice. There is an advantage to it later only when large plants are set, when conditions are unfavorable for growth, and when the root system is much reduced in taking up plants. Then it may be best to pinch off the outer leaves 2–4 inches from the base before setting. In general, reducing the leaf area delays development.

WATERING. If water can be applied without wetting the tops, especially during cloudy weather, losses due to damping-off are reduced. The object is to irrigate rather than sprinkle. The surface of the soil should not be allowed to dry out before the seedlings become well established, but keeping the soil soaked

should be avoided. Withholding water for 7–10 days prior to field planting is an effective method of hardening (see Premature Seedstem Development). But it is important, especially with plants in flats, to give a good soaking just before setting in the field.

Soil

Since celery has a high water requirement, muck soil, with its very high water-holding capacity, is ideally suited to it. Though rotation with other crops is advisable, celery can be produced almost continuously on the same land year after year, if good soil management and disease and insect control measures are practiced.

The Michigan muck soils are grouped as [251] *low-lime, p*H 4.5 or less; *high-lime, p*H 4.6–7.0; *very-high-lime, p*H 7.1 or more. Celery is sensitive to extremes of soil reaction. The very strongly acid mucks do not produce well until the acidity is somewhat decreased by proper liming. An alkaline soil may result in "cracked stem." Muck soil within the range of *p*H 5.0–7.0 is suitable.

Planting

Early celery is transplanted outdoors in late spring. Late or storage celery is planted in early summer. Cool weather is usually desirable at planting time, but exposure to low temperature may, as discussed later, cause bolting. The plants may be set on the level, in trenches, in furrows, or on beds, and by hand (with a dibber or trowel), with a slowly drawn field transplanter, or by means of a power machine. By hand, a dropper and two setters may set 15,000 plants in a day, whereas two men on a machine can set 30,000–50,000 plants. If the rows run north and south the sun shines on both sides of the plants, which has some advantage over rows that run east and west with the sun shining most of the time on the south side of the row.

Spacing of Plants

Celery is usually spaced 5–9 inches apart in 4- or 2-row beds on muck soils. For hand cultivation, or where blanching is not done, the rows may be only 1½ feet apart. The spacing in the

row is usually closer in eastern than in western areas. The beds are commonly 2½–3 feet apart.

Premature Seedstem Development

Often a serious problem in growing celery is the undesirable development of flowering shoots, or "bolting to seed." A com-

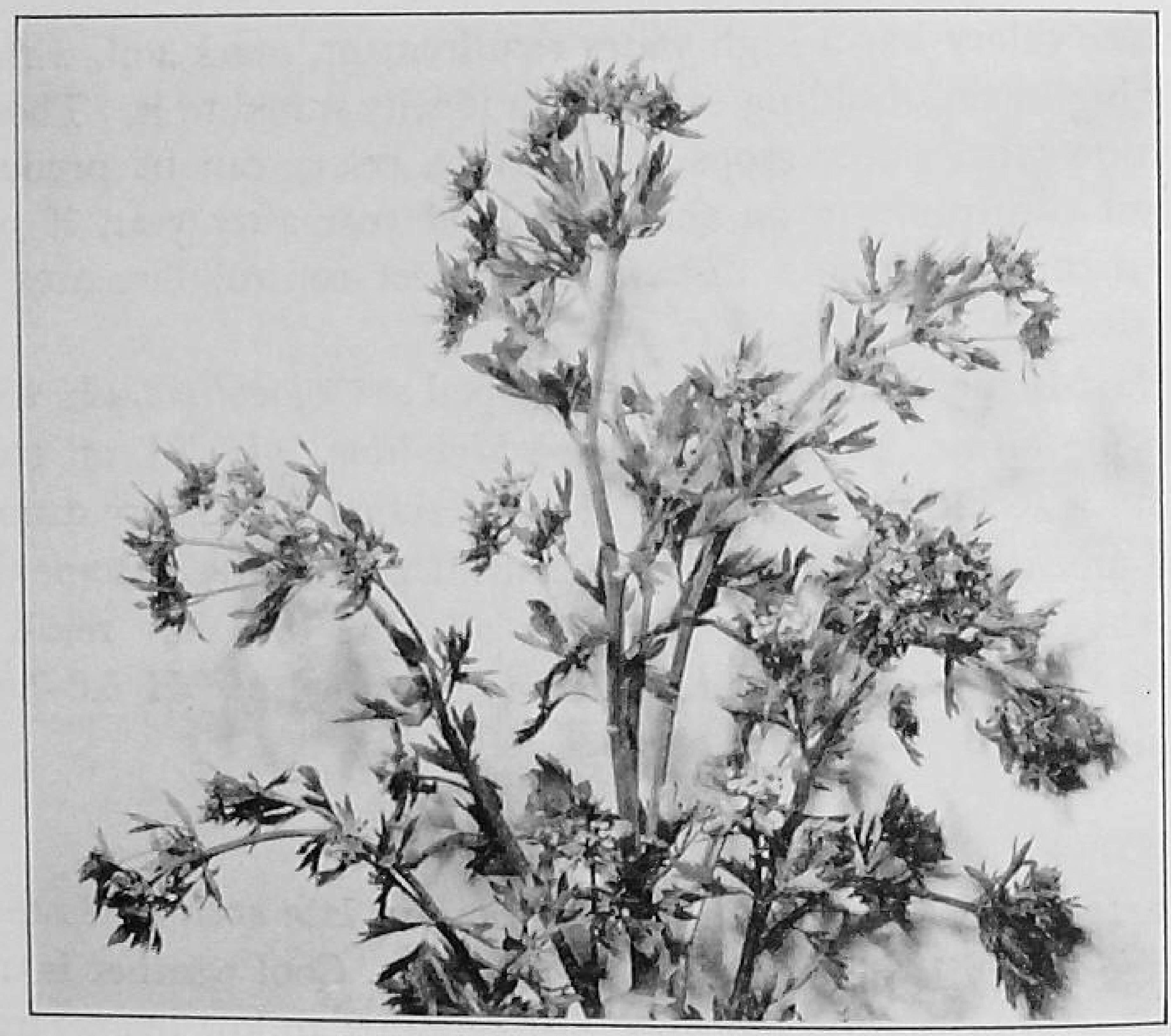

Fig. 43. Undesirable premature seedstalk development in celery due to exposure to cold.

mon belief some years ago was that bolting of celery is caused by any condition that checks the growth of the plants, by poor seed, and by early sowing of seed. A check in growth due to drying out, lack of nutrients, crowding, and similar conditions, was assumed to be at the bottom of the trouble. But it is now known that bolting is mainly due to exposure of young plants to 35–50°F. and that the amount of such bolting increases as the exposure is lengthened.

Growers producing plants, especially for the early crop, should maintain underglass temperatures of 60–70°F. and harden the plants by withholding water the last 7–10 days before field setting rather than by subjecting them to cold. The plants may wilt

during the day, but if they revive by evening they need not be watered until the day before setting in the field. Factors that check or slow the rate of growth actually delay bolting. Even with plants that have been predisposed to bolting by exposure to cold in their early stages any condition that delays growth also retards the development of seedstems. There are possibilities [433] for controlling bolting by applying hormones before the temperature induction of flowering occurs.

Heredity is involved to some extent. Some strains seldom bolt, whereas others may bolt 100 percent under the same conditions. But regardless of the heredity, seedstems are seldom produced unless the plants have been exposed to 35–50°F.

Manure and Fertilizer

Celery is shallow rooted and a poor forager, but it is a heavy feeder. A high level of plant food must be present in an available form. Good quality depends on continuous, steady growth. Generally the plants become well established in early summer, make little progress in midsummer, and grow rapidly in late summer. It is desirable to apply 10–15 tons of manure per acre on mineral soils, or twice this amount in irrigation districts, preferably in autumn.

Celery needs only 25 ppm. of nitrate nitrogen (soil solution concentration) during the first third of the growth period and 50 ppm. thereafter. Fertilizer may be applied: (*a*) just before the final preparation of the field before planting; (*b*) as a dressing along the row in bands about 3 inches from the plants. After the plants are established and the root system begins to function, or 1–2 weeks after planting, 100–150 pounds of a nitrogen fertilizer, such as sulfate of ammonia, may be applied per acre for the early crop. Three weeks later, nitrogen may again be applied at the same rate.

Cracked-stem and "cat scratches" may result from a lack of boron. A brownish mottling first appears on the outer margins of the younger leaves. The petioles become brittle, and brown stripes show in the epidermis over the vascular bundles. Then transverse lesions appear, and the epidermis and adjoining tissue curl outward. Exposed tissue becomes dark brown. About 2 weeks after planting, borax, about 10 pounds per acre, may be

applied near the base of the plants, either dry and mixed with sand to give it bulk, or as a stream spray.

Copper (100 pounds copper sulfate per ton of fertilizer) is often beneficial on new muck land, but on older muck enough copper is usually added where copper fungicides are used.

Irrigation

Celery needs much water while growing. In many areas rainfall is not sufficient nor timely for this crop. It is wise to apply water before the first indication of wilting or any check to growth. When overhead irrigation is used, the water is usually best turned on in the evening. For some crops, water warmed by the sun is better than cold water, but this is not true for celery. Overhead irrigation may increase certain diseases. On some mucks, the level of the ground water can be raised by means of dams or ditches.

In irrigated districts water may be run through furrows a day or two before planting. The dry top soil is skinned off along the line where the plants are to be set. This leaves a shallow, crescent-shaped furrow which later guides the water. The plants are set in moist soil at the bottom of the furrow. When the plants are set in a few rows in a large planting, water is run through the furrows. The plants must be set at the proper depth along the bank or edge of the furrow so that the heart of the plant is not covered. The soil is firmed around the roots to keep them from drying out and to keep soil from washing away during irrigation.

Though celery is moisture loving, if it is grown on soil with a heavy, impervious subsoil, it will not make good growth. Too much irrigation favors development of root rot, and soft, succulent stalks.

A check to growth or high temperature may encourage *blackheart.* The heart leaves become blackish, and the tips of older leaves often turn brownish black and shrivel up. The chief control is to maintain conditions for steady growth. The soil should be kept moist but not waterlogged. Secondary infection following stings of the tarnished plant bug promotes a condition resembling blackheart.

Cultivation

Celery grows slowly and is soon injured by weeds. It responds more to cultivation for the purpose of maintaining a soil mulch than do most other crops. Cultivation is begun when the plants have made enough root system to hold them in the soil and is kept up almost until harvest. Shallow tillage is desirable. Deep tillage loosens the soil below many of the roots, causes drying out, and thus checks growth, possibly causing pithy stalks. (See also Chapter 15, Weed Killers.)

Blanching

Excluding light from the stalks while the plants are still growing causes failure in development as well as a loss of chlorophyll in the stalks. Blanching is not practiced now as much as formerly, even with the early types.

When the plant has formed stalks of sufficient length, it is time for blanching, if it is to be practiced. Blanching should not progress too far, or the celery will lose its flavor, become too pale in color, rot, or become pithy, and it will not keep well. The length of time needed for blanching depends upon the type of celery, rate of growth, temperature, and market demands. In midsummer, golden varieties blanch well in 2–3 weeks. When late varieties are blanched in soil in the field the process takes about 3 weeks. Celery to be used as green celery is not blanched.

Soil method. Blanching with soil gives some protection against freezing in autumn. As cold weather approaches, soil may be worked up to the tops of the plants so that they can be held 2–3 weeks longer in the field. When it is banked high the crop can stand light frosts without damage.

Banking should not be done when the soil is quite wet as it then adheres to and discolors the plants. Heart rot may greatly increase in the field if the soil around the mounded plants is soaked. Banking celery with soil in warm weather may cause it to decay. Another objection to banking in the early crop is that the season in which it matures is usually warm and such blanching favors development of leaf spot and root rots and injury to the stalks.

BOARD METHOD. Boards 1 inch thick, 10–12 inches wide, and 14–16 feet long may be placed on each side of the row, straight upon their edge to avoid warping, and held in place by stakes, by wooden strips nailed across the tops, or by wires bent in the form of double hooks 6–8 inches long. The wires are placed over the upper edges of the boards at the end and at intervals in between. A little soil is thrown up along the base to prevent light

FIG. 44. Board method of blanching early celery.

entering there. The boards should not be much higher than the plants will grow, because if the tops are bleached it spoils the appearance of the celery. Celery blanched in this way is clean, but much lumber is needed.

PAPER METHOD. Tough, heavy kraft paper, laminated with waterproofing asphalt and with twine between the layers is bought in rolls. It is cut into strips 10–12 inches wide, set on edge against the plants, and held in place by wires bent in the shape of an inverted U with each leg about 18 inches long. The wires are placed over the row with one leg on each side, and the ends are pushed into the soil 6–8 inches. Heavy asphalt roofing paper, without tar, is also used.

ETHYLENE GAS METHOD. Ethylene gas hastens ripening of the harvested crop by speeding up enzymatic action, but it bleaches the color out of the tops of the leaves so that the celery may

appear old and wilted. The gas is used, 1 part to 10,000 parts of air, in a fairly humid atmosphere, at about 65°F., in a room or enclosed space with little leakage of air; one treatment is given for self-blanching and two for green varieties.

Harvesting

In most areas each plant is cut 1–2 inches below the surface of the soil with a knife. The work often is done with a sharp, U-shaped bar mounted on a small tractor, which runs beneath the roots. The plants are then trimmed. Early types become soft when planted late or held too long and should be marketed as soon as ready. Celery should be taken from the field soon after it is cut as exposure to the sun and wind causes it to wilt. Celery for winter use is left undisturbed outdoors as long as practicable.

Sensitive workers may develop dermititis on the hands and forearms while harvesting and stripping celery in the field, and contact with rotted and ripe celery is especially hazardous. The injurious factor, to white workers (colored workers are less sensitive), is ascribed to dextro-limonene, the oil in celery.[149]

Harvesting methods in Florida.[49] In the Sanford area celery is cut by means of a push knife (a sharpened loop blade which cuts the root of the stalk just under the soil surface). The blades are mounted on two wheels and are designed to be pushed along the row. But often the wheels are removed and the blade is pulled along the row in short, quick jerks as the worker walks backwards. Two push-knife cutters work 1–2 rows ahead of 20–30 strippers, who work across the rows. Each stripper handles only the celery within his "down" (space staked out about 15 feet wide). The strippers use knives with 4½-inch blades to trim the roots after defective ribs are removed by hand from each stalk; 3–8 cuts are made per root (like a pencil). Then the celery is placed in stacks of 50–100 stalks. Following 3–4 strippers is a packer who places the celery in field crates. After packing the tops are cut off with a saw or machete (1–2 toppers to 20–30 strippers).

In the Sarasota area each two push-knife cutters are followed by a worker who pushes the celery over in one direction after it is cut. The cutters work 5–8 rows ahead of the rest of the crew. After the celery has been pushed over, 5–8 workers walk along the rows and trim the roots with hand knives, usually without picking up the stalk. Only one cut is made for each root that needs trimming, the roots being cut off squarely. About 15 strippers follow the root cutters down the rows and pile 2 rows together for 5–10 packers who fill the field crates which they pull along the row as they work. The tops are then cut off with a saw or a machete.

In the Belle Glade area celery is cut by means of a hand knife with a 5- or 6-inch blade. As each stalk is cut it is stripped and piled in rows, and 2–3 rows are stacked together. One packer usually packs for 2–3 strippers. A topper follows the packers and cuts off the tops with a saw or a machete.

Washing. Celery for storage should not be washed. When celery is to be washed for shipment, cold water should be used, as moisture and high temperature encourage rots, and precooled celery reaches the market in the best condition. In washing, if the outside skin is broken it becomes rusty and unattractive. In packing houses, a belt carries the celery through a wash chamber where it is sprayed from above and below.

Packing. Packing follows washing, unless the celery is placed in the 16-inch crate for storage or some shipment. Most warehouses have these features: an unloading platform, a conveyor chain on which the celery is placed either before or after stripping, a pressure washer, conveyor chain from which the washed celery is selected for packing, packing tables, a series of conveyor chains to move the filled crates to the precooler, sometimes a sorting room, a precooler, and a loading platform parallel to a railroad siding.

Most celery, wherever grown for shipment, is clipped to 16 inches long and packed with tops and butts reversed in alternate layers. The crate most generally used is $9\frac{3}{4} \times 16 \times 20$ inches (inside), with some slight variations in length as between the nailed and wire-bound types.

Celery hearts, when bunched, usually consist of 2–3 stripped small stalks. They may be wrapped with paper or some transparent material, or tied with colored material or elastic bands. The trimmed stalks are 10–12 inches long, stripped to the more bleached and clean portion, and preferably of a full-heart type.

Storage

Celery will absorb foreign flavors and should be placed in a storage free from odors of other products. It is unwise to store celery that has been crushed, has broken stalks, is diseased, or has been damaged in handling or by frost.

Celery may be stored in trenches and cellars, but, commercially, refrigerated cold storages are now used almost exclusively, as they are more efficient, and because more cold storage space is becoming available each year.

TRENCH METHOD. Outdoor trenches may be made 1–2 feet wide and deep enough so that only the leaves reach above the top. The plants and roots with some earth on are lifted and placed tightly in the trenches, which have loose soil in the bottom. The trenches are then covered with boards to keep out rain, and the boards are arranged so as to provide adequate air circulation. Insulation such as soil, straw, and manure are added as colder weather approaches. Temperature and moisture cannot be controlled with trenched celery.

CELLAR STORAGE. Before the celery is stored, some of the outer leaves may be removed. Rotting of the heart in storage results from lack of ventilation, from too warm a cellar, and from watering the plants from above. Freezing must not occur, but the higher the temperature the shorter the storage period. Late varieties keep best. When celery is kept well into the winter, it may be desirable to repack it once or twice, removing all decayed leaves or specimens.

COLD STORAGE. Successful cold storage commences in the field. A cold storage is not a magician's box where one can place poor-quality produce and have it turn out as first quality. The crop should have been well sprayed so as to be free from diseases and insects. Harvesting should be followed immediately by precooling and storage.

Celery is usually packed in crates. When dug, it is given a preliminary trimming in the field. The plants must be carefully handled to avoid bruising. Precooling is done by spraying the filled crates with cold water. This rapidly removes the field heat prior to storage. Celery keeps best at 32°F. with a relative humidity of 95–98 percent, both kept uniform. The higher humidity is best for avoiding wilting if forced air circulation is provided to prevent condensation of moisture.

At first, normal ripening processes go on; later, there is a breaking down of the cells and decay. Sugars and other products are translocated from outer to inner stalks. The more resistant pectic compounds of the middle lamella change to less resistant ones. Both reducing and total sugars in the leaves decline as time from harvest progresses; this decrease is accompanied by an increase in the stems (translocation there) until toward the end of storage. Soluble nitrogen increases in both leaves and stems until toward the end of the storage period; then

there is a marked decrease in the leaves and a slight decrease in the stems. Insoluble nitrogen is high in the leaves at harvest time and, in general, decreases from then to the end of storage. At low temperature, the changes take place slowly. The aim, therefore, is to keep the temperature as low as possible without freezing.

Heat is given off by celery because of respiration. The air at the top of a storage room not equipped with forced air circulation may be 3–4°F. warmer than that at the bottom, and the temperature in the center of the crate may be 2–3°F. higher than that of the surrounding air (thus the 16-inch crate has a merit over the 24-inch). When stacking crates in the storage room, 1×2 or 2×2 inch strips are placed between crates and floor.

Since injury on the petioles may result from slight freezing under certain conditions, and since such injury reduces the marketability of affected plants, it is important to consider time of harvest in relation to weather. When the minimum temperatures are 32–45°F. for the 3 weeks preceding harvest, the grower may risk harvesting after the first slight frost; but when the temperatures just before harvest are above 50°F. it is wise to harvest before frost. If the crop undergoes a frost in the unhardened condition, it may be unwise to risk long-storage charges.

Pitting is characterized by the development early in storage (2–6 weeks) of irregular sunken areas in the stalks. These sunken areas later develop a brown color. The cause of pitting seems to be the result of several factors working together. Certain varieties seem more susceptible than others. The soil nutrients should not be out of balance, e.g., low phosphorus and very high potash, or deficient in magnesium. Pitting may also be associated with freezing of the tissue immediately under the skin. Minute pockets of water may freeze and cause a breakdown of the tissue which shows up later as pitting, especially if the storage drops to 31°F. Late, soft growth may predispose celery to pitting.

Insect and Disease Control

Celery leaf tier is a small, greenish caterpillar that webs the leaves; holes are made in the stalks. The main damage occurs

rather late in the year. When two DDT sprays or pyrethrum dusts are applied within ½ hour, the first brings them out of the heart leaves, and the second kills them.

Tarnished plant bug is an active bug about ¼ inch long and brown mottled with shades of red and yellow. It sucks the juice of the stalk near the upper joint, causing a blackening there. The leaflets above this joint become pale in color. Control is adding DDT to the blight sprays or using a fixed copper dust that contains DDT.

Carrot weevil, on muck soil, tunnels the hearts of the plants and dwarfs or kills young plants (see under Carrots). *Corn earworm* may eat the hearts and stems (see under Sweet Corn).

Late blight may start in the seedbed or in the field soon after the plants are set out and continue to develop even in storage. Brown spots with tiny black specks develop on the leaves and petioles. *Early blight* shows as dead ash-gray velvety spots, especially in warm, moist weather. *Bacterial blight* shows as brown, translucent spots on the leaves. For these three blights, controls are seed treatment (see Table 5) and spraying or dusting with copper substances starting in the seedbed and continuing at frequent intervals.

Fusarium yellows or wilt is a vascular disease, causing stunting, yellowing, or chlorosis of the leaves and a yellowish or reddish discoloration in the stalk near the crown. The soil once infested remains so indefinitely. Dark-green varieties are highly resistant, as are Michigan Golden, Golden Pascal, and Cornell 19.

Pink rot shows as watery spots at the base of older plants followed by white, cottony fungus growth which develops a pink color. The stalks rot and taste bitter. Controls are to avoid planting celery, lettuce, or cabbage in immediate succession on the same soil and to remove and burn infected plants.

PARSLEY

Parsley is probably the most widely grown garden herb. The leaves are used to decorate or garnish meat platters and other dishes, and in sandwiches; it is minced and strewn over potatoes, carrots, or peas; and a sprig gives a characteristic taste to soups, sauces, and stews. It is very high in vitamin C. Parsley is

mostly used green, but the leaves may be dried, powdered, and kept in airtight bottles.

Parsley is hardy to cold and sometimes winters over but is usually grown from seed each spring. A few feet of row will supply the family, and a few plants moved to a coldframe in autumn will give a supply in early spring. Plants are often potted and grown indoors in winter.

Varieties

The *Plain* or *Single* type is grown chiefly for use in soups. *Champion* and *Paramount* (All-America, 1936) are leading varieties of the triple-moss-curled type. *Evergreen* (All-America, 1940) is less finely cut but is a heavy yielder and seems somewhat more resistant to drought.

Producing Parsley

Soil and Fertilizer

As the seedlings are delicate during early stages of growth, the soil should be mellow, not subject to baking, and free from clods and stones. A rather moist soil is best. The use of manure or commercial fertilizer usually increases the yield.

Seeding and Spacing

Parsley may be seeded as soon as the ground can be worked in the spring. Earliness and surer results are obtained by starting the plants under glass in late winter and moving them to the open ground in early spring. The seed germinates slowly, sometimes requiring 4–6 weeks (the ancients explained this by saying that the seed went to the devil and back again nine times before germination). A few radish seeds scattered in the row will serve as a guide in cultivation before the parsley plants appear. Depth of seeding is ⅛–¼ inch. Parsley rows should be 15–24 inches apart, with the plants 4–8 inches apart in the rows.

Harvesting

In harvesting, the outer and larger leaves are removed successively, and the plant continues to produce for several months.

Taking tips from individual plants, rather than stripping them, results in a greater total yield and better quality. When parsley has stood for some time, it becomes coarse, but young growth can be renewed by severe cutting; this operation is also helpful to defer undesirable flowering, which is surely hastened by leaving the plants alone.

Growing Plants Indoors

A pot of parsley in a window during the winter is both ornamental and useful. In autumn, a thrifty plant is selected, and the roots are cut with a sharp shovel at a slight angle so that the taproot is cut well below the crown. The plant is then watered and left for 1–2 weeks. Meanwhile it makes fibrous roots which hold the soil together and facilitate transplanting. The plant is given a good watering on the day before it is lifted.

When taken up, the ball of soil is reduced to fit in a 7-inch pot. It is made quite firm in the pot, and then placed in a shady place, watered, and allowed to remain until frosts compel its removal indoors. In potting, not much more than the center young leaves are left. Occasional use of a mild fertilizer stimulates growth. Parsley roots dug up roughly and potted will produce leaves eventually, but the winter may nearly be over before they are available.

8 · GREEN CROPS

COMMON SPINACH

Spinach is a vegetable, or potherb, that is much used for boiled greens. The vitamin and mineral values that have been claimed for spinach and the comic strip on the activities of "Popeye" have been significant factors in developing interest in this crop and in breaking down juvenile resistance. About 125,000 acres of spinach are grown annually in North America for the fresh market, canning, and freezing.

Spinach is available from the northern garden for only a short season, mainly in late spring, because it is prone to produce flowerstalks during long days and warm weather. Spinach is much grown for canning and as a winter crop in the milder regions.

Yields of 35 pounds from 100 feet of row, or 10 tons per acre, are commonly obtained.

History

Spinach was unknown to the ancient Greeks and Romans. It was probably first cultivated by the Arabs, who introduced it into North Africa. The Moors took it to Spain, whence it spread through western Europe. The spiny-seeded form is the oldest type, and the smooth-seeded form arose by gene mutation.

Prickly or Winter is probably the oldest cultivated variety. Introductions by periods are as follows: *before 1885*, Amsterdam Giant, Viroflay, Bloomsdale, Gaudry, Victoria; *1885–1900*, Long Standing Prickly; *1900–1925*, Hollandia, King of Denmark, Juliana, Virginia Savoy, Dark Green Bloomsdale, Long Standing Bloomsdale, Nobel; *1926–1950*, Old Dominion, Canner King, Winter Giant, Darkie, Viking, Presto, Del Monte, Virginia Savoy Wilt Resistant, Winter King, Domino.

The word spinach comes, not from spina, a thorn, even though its seed is prickly in some types, but from *Hispania*, Spain.

Classification and Varieties

A. Round seeded.

1. Smooth leaved (or slightly savoyed in cool weather).
   (*a*) Early bolting or not long standing: Broad Flanders, Gaudry, Viroflay, Eskimo Giant.
   (*b*) Slow bolting or long standing: King of Denmark, Viking, Nobel, Darkie, Giant Fillbasket, Northland.
2. Savoy leaved.
   (*a*) Early bolting or not long standing.
   (i) Mosaic resistant: Virginia Savoy, Old Dominion.
   (ii) Not mosaic resistant: Savoy Leaved or Bloomsdale, Dark Green Bloomsdale.
   (*b*) Slow bolting or long standing.
   (i) Mosaic resistant: Domino.
   (ii) Not mosaic resistant: Juliana, Long Standing Bloomsdale, Summer Savoy.

B. Prickly seeded.

1. Smooth leaved (or slightly savoyed in cool weather).
   (*a*) Early bolting or not long standing.
   (i) Mosaic resistant: Japanese Prickly, Manchuria.
   (ii) Not mosaic resistant: Prickly or Winter, Hollandia, Dark Green Prickly Seeded.
   (*b*) Slow bolting or long standing: Amsterdam Giant.
2. Savoy leaved.
   (*a*) Early bolting or not long standing.
   (i) Mosaic resistant: Presto Blight Resistant.
   (ii) Not mosaic resistant: Presto.

Dark Green Bloomsdale is the leader for winter culture in Texas and the South. *Long Standing Bloomsdale* is an early variety for home and market gardens—valuable as a successor to Dark Green Bloomsdale for spring sowing, not for winter-over crop. *Nobel* is noted for its large, smooth leaves and slow bolting. *Viking* is slightly darker, larger, more crumpled, and somewhat longer standing than Nobel. *King of Denmark* is one of the slowest smooth-leaved varieties to bolt; the leaf color is duller than in Nobel. *Darkie* resembles King of Denmark, but the petioles are shorter, and the blades darker green, smoother, and thicker. *Domino* plant is large, dark green, rather flat growing, not very heavily savoyed, and mosaic resistant. *Juliana* is not important in any commercial shipping district owing to its small

size and slow growth. In home and market gardens it is long standing and can be spaced closer than other sorts.

Virginia Savoy is mosaic resistant, very quick to bolt in spring, and adapted mainly for fall culture in regions with mild winters. There is a wilt-resistant strain of Virginia Savoy in which about 70 percent of the plants survive the disease on badly infested fields, whereas only 30 percent of the commercial strains live. *Old Dominion* is mosaic resistant, is popular in Texas, and is used mostly as a spring crop; for example, in Virginia the seed is sown from mid-October to mid-November. *Viroflay* is used for early market and canning, mostly in California and a little in Texas. *Amsterdam Giant* is chiefly used for an early canning crop in California but is being supplanted by dark-green strains of *Hollandia* such as *Dark Green Prickly Seeded.*

Plant Characteristics

The fibrous feeding roots are borne directly on the thickened taproot. There are two distinct stages in the life history of the plant, viz., crown development and flowerstalk formation. A crown, which is really a longitudinally compressed stem and from which a number of rosette leaves (edible part of the plant) arise in nearly the same plane, is formed near the ground. The savoy form (blistered or crumpled) is due to continued growth of the parenchyma between the veins of the leaf. After development of the crown and rosette leaves, the stem may bolt to seed and the plant is then of little edible value. The length of time between the rosette stage and bolting is an important economic factor.

Producing Spinach

Spinach is a quick-maturing crop and makes its best growth in the cool weather of spring and early summer, when it may be used to occupy land for only a short period. It is a good fall and winter crop in areas with mild winters. It tolerates frosts better than most vegetables.

Bolting

Hereditary factors play a part in determining the time at which seedstems develop. An example is the successful devel-

opment of long-standing varieties, which may commence stalk elongation several weeks later than others. (See also sex classes under Spinach Seed Production.) Spinach bolts quickly under

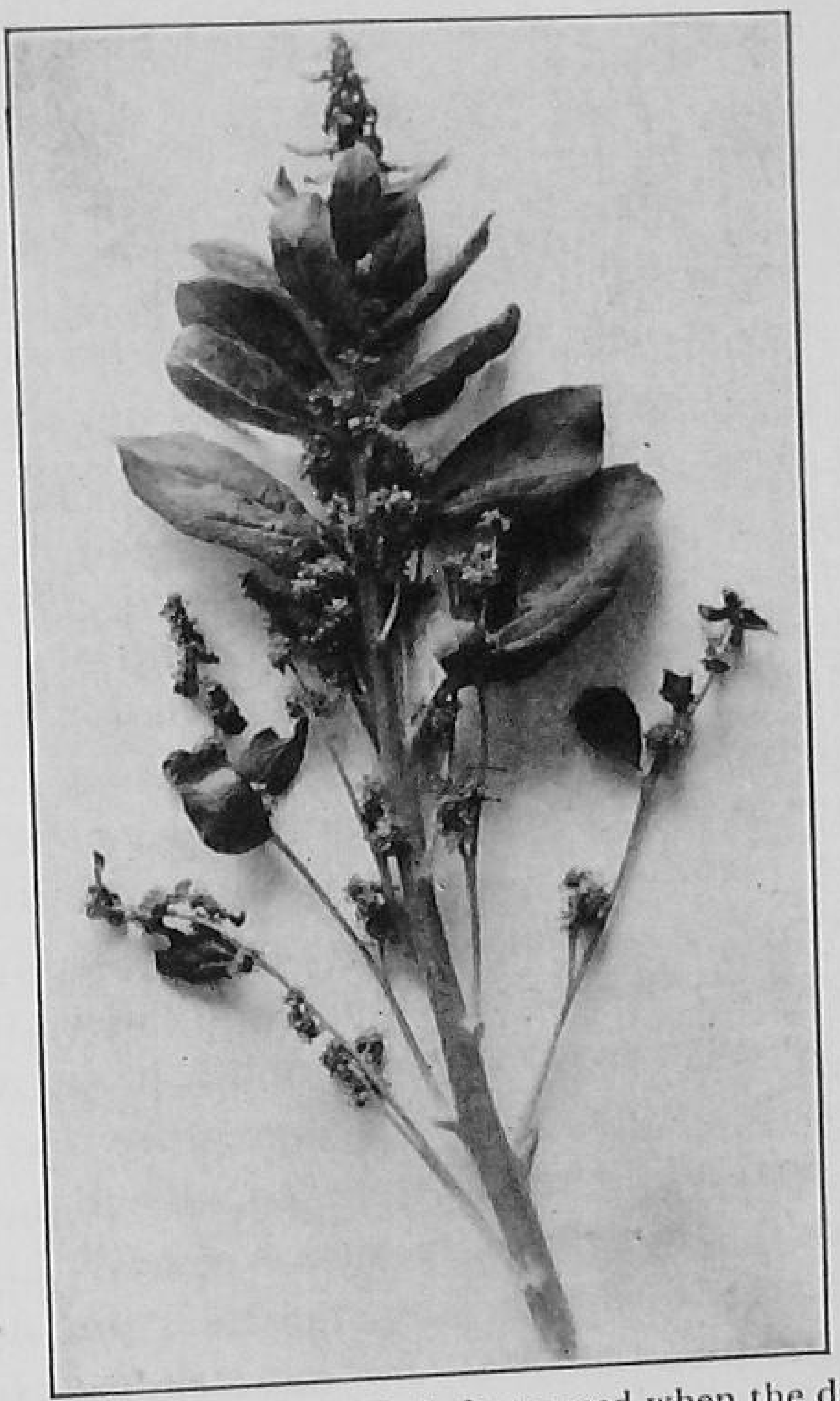

FIG. 45. Spring-sown spinach quickly bolts to seed when the days become long.

long days and warm weather, and so it seldom succeeds in summer. Cool weather may modify the effect of light to the extent that spinach grown in cool summers may not bolt quickly.

ENVIRONMENT [246]

EFFECT ON PLANT HABIT. Cool weather, or cool nights at least, tends to make the plants more erect. This applies in the same area in different years, or in different areas in the same year.

EFFECT ON SAVOYING. Low temperatures, especially at night, cause intense savoying in savoy varieties and a crumpling or pebbling of the base of the blades in smooth-leaved sorts. High

temperature, especially if uniform, decreases the savoying. The degree of savoying may change with a change in air temperature of but 4–5 days' duration.

Effect on color. In a rich soil, cool temperatures result in a heavy bloom and deep-green color. With medium or favorable temperatures for rapid growth, the amount of bloom is less and the plants appear lighter green. With very high temperatures the edges of the older leaves turn yellow, followed by the younger ones toward the center of the plant. If high temperatures persist long enough the entire leaf may become yellow and the plant may die owing to a root or ground-line disease.

Effect on plant size. With abundant moisture and fertility, maximum yield is attained under short days and moderate to warm temperatures, or when the relation between day length and temperature is such as to deter bolting and yet produce fastest growth of leaves. The optimum relation between these two factors differs among varieties with respect to both plant weight and spread or width. Uniformly high temperatures cause very prostrate plants, and low growing temperatures or cool nights produce taller or more erect plants. But repeated freezing of fall-grown plants results in a flattening down of the leaves.

Effect on number of leaves. Number of leaves is related to length of growing period, but temperature and nutritional conditions at critical periods may be equally important. Leaf production per day of growing period is usually highest under long days and relatively high temperatures. But decreasing or short length of day and 50–60°F. are more efficient in increasing the rate of leaf initiation.

Effect on leaf form. Blade length and width depend upon (*a*) the length of the growth period and (*b*) the environmental complex during growth. Uniformly moderate to high temperatures and long days favor rapid growth, but the final size of blade depends upon both the rate of growth and the length of growth period. High temperatures may shorten the total growth period so much that final leaf size is smaller than under cooler weather. Smooth types tend to produce longer leaves than the savoy type under short days and cool weather.

Cool weather, at least at night, causes a curling down or under of the tip, edges, and basal lobes of the blades. This obscures

the true halberd shape of the savoy varieties and of King of Denmark, and makes the blades appear oval or elliptical.

Effect on petiole. The relative amount of petiole is commercially important, especially to the canner. Conditions that result in the largest size of leaf also produce the longest blades and, conversely, the shortest petioles. Hence most of the growth in petiole length is made early, and, when conditions favor continued or rapid growth, growth in blade length is more rapid than that in petiole length.

Effect on leaf health. High temperatures cause yellowing and subsequent death of the lower leaves. A shortage of soil moisture accelerates the process. But temperatures above 100°F. produce yellowing of the lower leaves, even in soil apparently well supplied with moisture.

In early winter at Arlington, Va., 20°F. did no apparent damage; but when the temperature dropped to 9°F. and minima below 29°F. occurred for 9 consecutive days in mid-December, much death of blade tissue followed. In February at Winter Haven, Tex., mature, vigorous plants were exposed to 18°, 21°, 34°, 26°, and 32°F. on successive days. This cold spell caused death of portions of the blade and splitting open and flattening out of the epidermis of the petioles. The damage was most severe on Hollandia, Juliana, and Long Standing Bloomsdale, and least severe on Virginia Savoy, Dark Green Bloomsdale, and King of Denmark, with Viroflay and Nobel intermediate.

Effect on quality. Fall-sown spinach (winter crop) contains more sugar and total solids than spring-sown spinach. High humidity favors tender, succulent foliage.

Soil

Spinach does best on soil that is rich and well supplied with moisture. A soil, e.g., muck, that gives a minimum of grit on the crop has merits.

Early-spring sowing is aided by having the land partially ready in autumn. Harrowing and smoothing should leave the upper 4 inches in a fine condition, level and compact.

A slightly acid soil (pH 6.0–6.7) is desirable. The yield may be only half as much at pH 5.0 as at pH 6.0–6.3. Low germination, yellowing and browning of the margins and tips of the seedling leaves, browning of the roots, death of many of the

plants and a slow growth of the remainder usually indicate too acid a soil. Injurious effects of acid soils may be due to aluminum toxicity rather than to the hydrogen-ion concentration. On muck, *p*H 5.2–6.0 is suitable.

On strongly alkaline soils yellowing of the leaves may occur, owing to deficiency or improper balance of iron, manganese, or other elements. Chlorosis due to lack of available manganese can be reduced by spraying with 0.004 percent manganese sulfate in early stages of the trouble. Or 100–150 pounds manganese sulfate can be broadcast before seeding. If the spinach is half grown or less when the chlorosis appears, it may be corrected by applying 50–100 pounds of manganese sulfate per acre. These small amounts of manganese sulfate may be mixed with soil or sand to aid in applying, or a seed drill may be used; larger amounts are dangerous. Spinach sometimes responds to copper sulfate and to borax on muck.

Manure and Fertilizer

To be of highest quality, spinach must grow rapidly and luxuriantly and with a good green color. Manure is usually applied to the preceding crops rather than to the spinach itself. Where there is adequate humus in the soil, fertilizer alone may be used. In Massachusetts, ½–1 ton of 5-8-7 fertilizer, harrowed in just before seeding, is good. In Virginia, fertilizer is usually not applied until after thinning unless the soil is quite low in phosphorus and potash. Immediately after thinning, a dressing of a mixed fertilizer is applied. This is followed with one or more applications of a nitrogen fertilizer.

The best kind and rate of fertilizer to apply varies with different soils and other conditions and must be determined by local trial. When spinach shows slow growth and poor color 2–3 weeks before cutting time, owing to abnormal growing conditions and not to unfavorable soil reactions, application of nitrogen, e.g., 200 pounds nitrate of soda per acre, may increase the size and thickness of leaves. If the fertilizer touches the plants, especially when they are wet, burning may result. Late spinach grows best [357] when the nitrate nitrogen concentrations are 50 ppm. or more throughout growth of the crop.

Wintered-over spinach often benefits from 300–400 pounds per acre of a nitrogen fertilizer, preferably half nitrate of soda

and half sulfate of ammonia, broadcast just before growth starts in the spring.

Rotation

Spinach needs only a short period from seed to harvest, and so it can be grown either before or after other short-season crops. Crops preceding spinach should be kept free of weeds. On upland soils, spinach may precede a late crop such as cabbage. On muck, spinach and late celery may be grown on the same land in a single year; spinach often is a fall crop after lettuce, onions, or some other crop harvested by late summer.

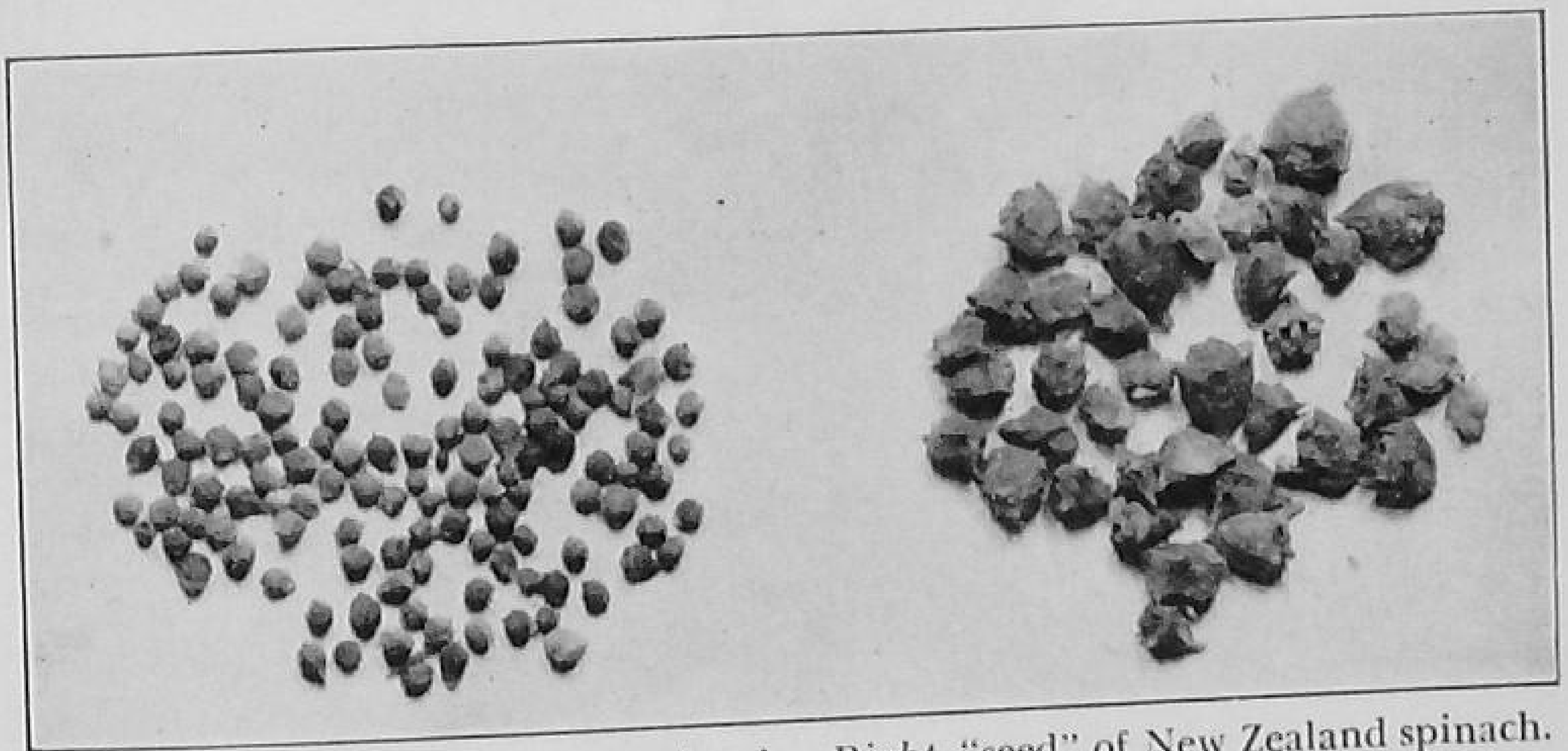

FIG. 46. *Left*, seed of common spinach. *Right*, "seed" of New Zealand spinach.

Seed Germination

Spinach seed more than a year old rarely germinates over 80 percent. Older seed is even less viable and germinates more slowly and irregularly for 2–3 months after it becomes mature. Germination occurs readily at 38–40°F., with good results at 50–60°F. and a decreasing percentage, but more rapid emergence, at higher temperatures. The ability to germinate in cool soil permits very early sowing in spring. Excessive rainfall tends to delay seedling emergence.

Seeding

Seed is sown outdoors as soon as the soil can be worked in spring. Seed that has been treated with a protectant (see Chapter 15) will not decay readily. The seed may be treated by seedsmen before it is sold. Successive sowings may prolong cropping, but

bolting may occur as the days become longer and warmer. Spinach reaches maturity 6–10 weeks after spring seeding.

In regions where only light freezes occur in the fall, growth continues until a late-summer or early-fall sowing can be harvested. If hard freezes do not occur until late November, sowings made about September 1 may yield well. If the late sowing fails to reach marketable size before freezing weather the spinach may winter over.

FIG. 47. New Zealand spinach has a spreading, sprawling habit.

The production of overwintered spinach in northern regions is a gamble. If there is not enough snow for adequate protection much damage may result. If the planting is covered with straw or strawy manure, freezing rain may solidify the winter covering so that the crop is damaged. But growers often attempt the fall-sown crop with Virginia Savoy and try to obtain adequate growth (¼–½ grown) to winter over. Such spinach can be marketed very early in the spring, thus releasing the land for other crops. In the South, the seed is sown from September to February.

Seed may be sown in rows as close as 12 inches, or the spacing may be increased according to the method of tillage. The seed is sown ½–1 inch deep. In Virginia, 4–6 rows 8–12 inches apart

are drilled on a bed. One man can sow about 20 acres a day with a tractor. About 10 pounds of seed are sown per acre if the rows are 12 inches apart.

Spinach plants usually are not thinned, as large individual plants are not needed for a usable product. The spacing can largely be regulated by adjusting the rate of seeding. If the plants are too crowded in the row, they may be thinned as far as 4–6 inches apart.

Harvesting

The size for harvest depends on the weather and, commercially, on the market. If the market is strong, plants with 5–6 large leaves are cut, but higher yields result if the plants are left longer. If the plants become old before being harvested, the quality of both the fresh and processed products is poor. Also, the percentage of waste is higher, owing to yellowing of the lower leaves and bolting.

Since spinach is very brittle when full of moisture early in the day, harvesting is best done in the afternoon when the plants are slightly wilted. Because of the turgidity of the plants, spinach should not be cut when wet with dew or rain. Some trimming is usually necessary to remove all dead, discolored leaves.

Much of the processing crop is cut with push hoes or with long-handled fork cutters. The long-handled fork cutter may be made from a four-tined fork around which is constructed a heavy-wire basket to catch the produce. The outside wires form a large enough basket to hold spinach from several feet of row. Any sticks, pieces of wood, or weeds are easily removed when the spinach is tipped over in being transferred from the fork into crates. The knife must be kept sharp. The plow-type cutter mounted on a wheel operates easily but requires the extra work of picking the crop off the ground. There is also a power cutter for large crops.

Spinach for market is usually cut below the crown with a knife or a push hoe, care being taken to keep the plants clean and to prevent undue breakage or bruising of the leaves. Cutting plants separately, and guiding the knife or push hoe so that few of the leaves need to be removed afterward, permits most of the trimming to be done on the spot. Spinach is usually

packed for market as it is cut. Much damage may be done by pressing the spinach into the container too firmly.

For shipment, 6–14 pounds of crushed ice are used with the spinach in a bushel basket, depending on conditions. Half the ice is placed in a layer at the middle of the basket and the

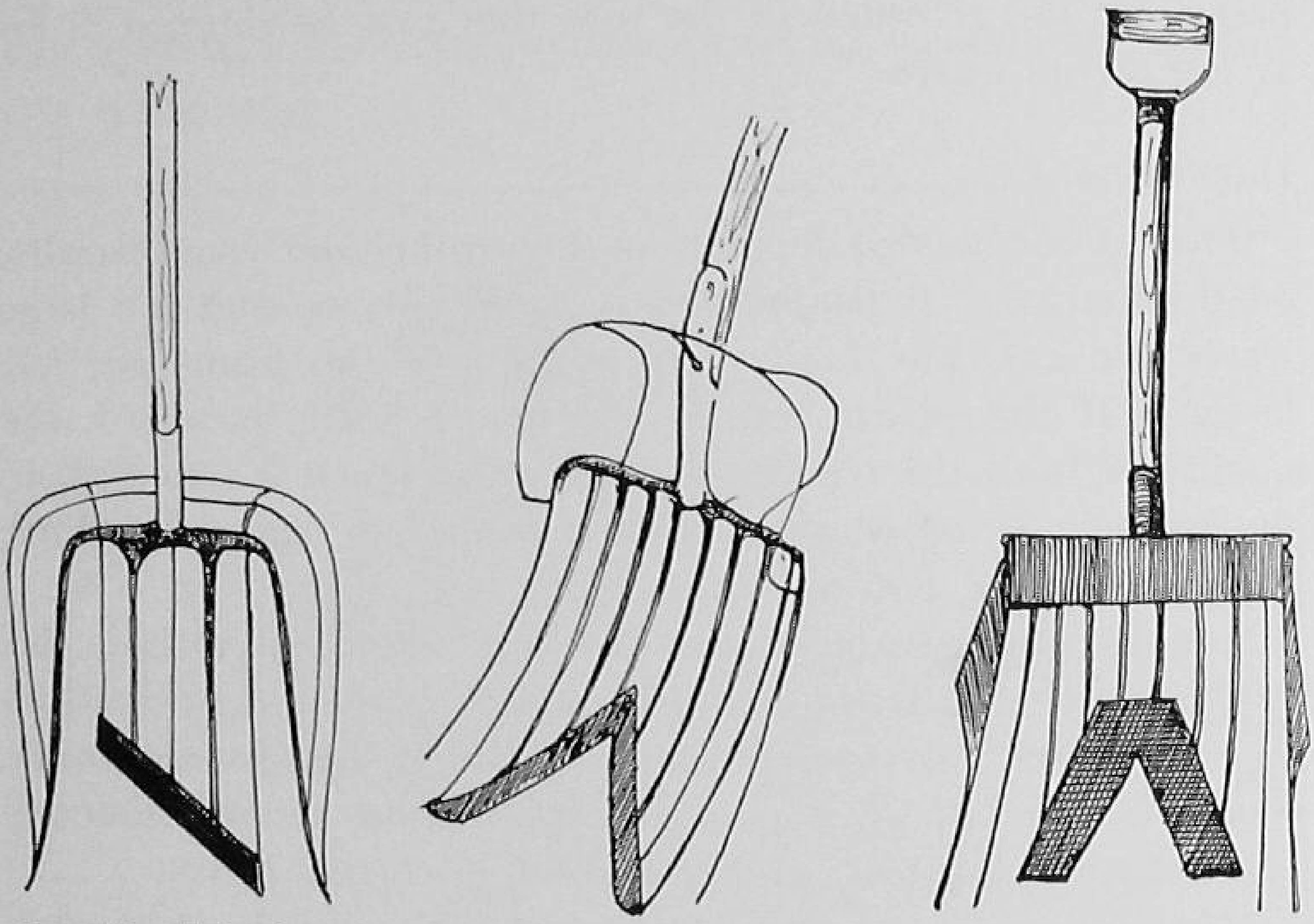

FIG. 48. *Left,* long-handled barley fork cutter. The thin-bladed cutting knife is welded to the two center tines and to the three additional supporting tines. The outside wires form a basket. *Center,* two butcher knives are welded together at an angle of 45°, after which they are welded to the tines on a potato fork. The middle tines are cut off below the blades and welded fast. A wire basket is welded to the top. *Right,* a V-shaped knife inserted in the center of the tines, with upright tin sides.

other half near the top. Advisability of washing before shipping is uncertain, because, in spite of care in handling, stems and leaves become more or less bruised or broken during the process. Decay may start in the injured tissues and cause serious damage during shipment and on the market. If washed, the spinach should be slightly wilted when it is handled, and care should be taken to avoid bruising or breaking. The spinach is dumped into a hopper from which it is carried by a conveyor through a series of pressure sprays. It comes out and falls into baskets which pass around another conveyor, and a definite

amount of crushed ice is added. The basket continues on its way and is filled up to a specified weight.

Spinach, wrapped in 1- or 2-pound, transparent-film bags, is one of the chief prepackaged vegetables. Fresh spinach harvested with the crowns intact is known as crown-cut spinach. When such spinach is used for prepackaging the crowns are cut off during the packaging operation. Spinach shipped with the crowns removed is called (in the trade) clip-topped or clipped spinach. As compared with crown-cut spinach, the clipped product requires less labor and time for prepackaging, and there is less waste in its subsequent use.

Storage

A relative humidity of 90–95 percent and 32°F. are best. Spinach freezes at 30.3°F. If it is packed tightly, respiration proceeds rapidly, and the heat so generated causes a rise of temperature in the center of the container. Spinach should not be left in tightly packed containers longer than a few hours, unless stored at low temperature. Under optimum conditions spinach keeps fairly well for 1–2 weeks or slightly longer if clean, crushed ice is used in the packages.

Insect and Disease Control

Spinach leaf miner flies may appear in spring and deposit eggs on the underside of the leaves. The maggots destroy the tissues of the leaves. Plowing soon after harvest and repeated thorough cultivation kill the pupae.

Aphids suck sap, and so cause stunting and wilting of the leaves. Control is dusting with nicotine, pyrethrum, or parathion.

Flea beetles eat small holes in the leaves or may skeletonize the leaves. Control is dusting with rotenone. *Seed-corn maggot* and *seed decay* may cause damage (see under Peas).

The chief spinach diseases are *mosaic, blight* or *yellows* (virus), *downy mildew, blue mold, white rust,* and *Fusarium wilt.* Mosaic-resistant varieties or strains have been mentioned earlier. Seed treatment with Arasan (see Table 5) is wise. Spraying or dusting with a carbamate helps control downy mildew.

KALE

Kale is a member of the cabbage family. It produces very large leaves which are used as greens and for soups.

The wild sea cabbage (*Brassica oleracea*), which is commonly found growing on the sea cliffs of England and other parts of Europe, is probably the ancestor of the various *Brassica* crops now in cultivation. Kale is the nearest of these to the parent form and has been cultivated for a very long time.

The Scotch kales or borecoles are our best-known kales. Collard, which is grown in the South for greens, is a kale.

Some examples of dwarf kale (12–24 inches high) are *Dwarf Green Scotch* and *Dwarf Blue Scotch*. The leading tall kale ($2\frac{1}{2}$ feet or more) is *Scotch Curled*.

Kale probably tolerates even more cold than cabbage. If the plants have not become too old, light fall frosts improve the quality. Kale thrives fairly well on rather poor soil, but good soils give best results. One plan is to transplant 1–2 feet apart, the dwarf type closer than the tall. The late crop is seeded in the field, and thinned to 1–2 feet apart in the row. Kale is harvested either by cutting the entire plant or by taking the larger young leaves.

CHARD

Chard, also known as Swiss Chard and Sea Kale Beet, is a foliage beet. Chard is the descendant of the ancient white beet of Sicily. The broad, succulent leaves are prepared for the table like spinach, and the leafstalks and midribs are cooked and served much like asparagus. The crop is useful from midsummer to fall. It withstands summer heat and long days better than most greens.

Chard deserves more general planting in home gardens in areas where gardening is rather difficult. One of its merits is that crop after crop of the heavy growth of outer leaves may be harvested without injuring the plants. A row 15–20 feet long will supply a family for the entire summer.

Varieties

Lucullus is the leading yellowish-green variety; there is also a *Lucullus Dark Green*. *Fordhook Giant* is larger, dark green, and

has broad, crumpled leaves and broad stalks. *Large Ribbed* (French Dark Green, Broad Rib Green, White Silver) has smooth, dark, glossy green leaves, broad midribs, and thick white stems. *Rainbow* is said to be Luther Burbank's cross of Improved Swiss Chard and beet; it has large crumpled leaves with stalks in white, pink, green, orange, and yellow. *Rhubarb Chard*, a Chilian or Brazilian beet, is red, but is not as vigorous as Lucullus. *Perpetual Beet* and *Spinach Beet* may be synonymous

FIG. 49. Swiss chard.

with chard, but in them it is the foliage only that has been developed.

Culture

Seed is sown outdoors in early spring, ¾–1 inch deep and thinner than beet seed. Earlier chard is obtained by transplanting outdoors as soon as danger of hard frosts is over. The storage root is small compared with that of the root-forming beet, but the large top needs space to develop. The "seed" (as with beet) contains several seeds. The plants may be thinned singly, first to 3–4 inches, later to 6–8 inches in the row, and eventually to 12 inches. The last spacing is also that at which transplants are set. The rows should be 1½–3 feet apart.

Harvesting

Chard is ready for use from early summer to midsummer, when sown fairly early, and can be used from then until the stems become fibrous. A good cutting stage is reached in 2

months from seed. For home use, chard is usually harvested by cutting off the outer stalks about 1–2 inches aboveground. New stalks are produced from the center of the plant, and repeated cuttings may be made. When the stalks are ready for gathering, they should be removed, whether wanted or not, to promote continuous growth. For marketing, all the stalks are often cut off above the growing point in the center, tied in bunches, and sold by the bunch or pound. If the plants are lifted in autumn with the roots attached, placed in a cool cellar, and covered at the roots with sand or soil, they may be held for some time.

Insect and Disease Control

Flea beetles are the chief insect pest affecting chard. Control is dusting or spraying with rotenone. *Leaf spot,* the chief disease, is controlled with a carbamate dust or spray.

9 · COLE CROPS

CABBAGE

Cabbage is adapted to a wide range of climates and soils. Best results are obtained in a cool environment and where the soil is well supplied with fertility and moisture. Cabbage has four distinct uses, viz., for salads, boiling, pickling, and sauerkraut. Early cabbage averages about 2–4 pounds, and late cabbage 4–6 pounds, per head; individual heads may be much heavier. A good yield per acre is 8–10 tons. Late varieties store best; they also make the best sauerkraut, not only because of their inherent high quality, but also because cool weather prevails at the time of harvest and later.

History

All cole crops, such as cabbage, cauliflower, Brussels sprouts, broccoli, kale, and kohlrabi, have sprung from the sea or cliff cabbage (*Brassica oleracea*). This plant probably originated in the eastern Mediterranean and Asia Minor areas, and was early found in western Europe (including the chalky cliffs of England and the coasts of Denmark and northwestern France), where it thrives under the cool, moist growing conditions.

Cabbage is mentioned by Plato as desirable in a vegetarian diet. Theophrastus, 350 B.C., in his *Enquiry into Plants,* mentioned smooth, wrinkled, and red types, as well as kale. Cato, in *De re rustica,* 200 B.C., referred to cabbage as an accelerator of digestion when eaten during the meal. Columnella wrote of cabbages as "in many forms the world over, for peasant and haughty king alike." Pliny mentioned a blistered-leaf type which probably is the ancestor of the savoy varieties.

The Romans introduced cabbage into the countries that they subjugated in war. Cabbages were cultivated by the ancient

Celts. The Latin name for the genus *Brassica* is from the Celtic *bresic*, meaning "cabbage." The word cabbage is from the French *caboche*, meaning "head."

Cabbage gardens were common in Denmark during Viking times between A.D. 800 and 1000. Kale was the type grown. Reference to head cabbage is obscure until early in the sixteenth century, but probably by that time head types were grown throughout northwestern continental Europe.

Emigration of Hollanders to Denmark to show the Danes methods of gardening was encouraged in 1520. Amager Island was placed at the disposal of the immigrants and became famous for its vegetables. Emigrants from Flanders and the Netherlands who settled at Battersea and other towns near London, England, about 1524 brought with them their local strains of vegetables. Cabbage was sown by Cartier in Canada about 1540.

There is no certainty as to whether the Amager cabbage (Danish Ballhead) originated on Amager Island or whether it was developed from seed brought there from Holland. Cris Hansen says: "It has been a custom that when an Amager family marries into another Amager family the bride brings local strains of cabbage seed as a gift, and in this way the different strains of Amager cabbage have developed, but no Amager family would ever sell to any foreigner. Until 1852 no seedsman had ever sold Amager cabbage seed." A. W. Van Zanton, Sluis en Groot, states: "Danish Ballhead was originally called Amack, which of course points to Denmark. In 1867, one of our Messrs. Groot visited together with Mr. L. Daehnfeldt, on the island of Amager a market gardener, who had worked up this strain. From this source our Mr. Groot took some seed to Holland, where he further grew it. We offered this strain for the first time in 1869. After some 10–15 years Vilmorin took up this variety and developed the big sale for it." [280]

Winningstadt, Early Jersey Wakefield, and Late Flat Dutch have been grown in America for more than 100 years. Varieties introduced between 1860 and 1900 include Charleston Wakefield, Improved American Savoy, Surehead, All Seasons, Danish Ballhead, Succession, All Head Early, and Mammoth Rock Red. Between 1900 and 1925, these varieties appeared: Ferry Hollander, Glory of Enkhuisen, Copenhagen Market, Wisconsin Hollander, Bugner, and Golden Acre. Between 1925 and 1950, the leading varieties introduced were Marion Market, Globe, Penn State Ballhead, Racine Market, Wisconsin Ballhead, Resistant Detroit, Chieftain, Wisconsin Golden Acre, Huguenot, Improved Wisconsin Ballhead, and Bonanza.

About 1900 the Pasteur Institute of Paris intimated that the longevity of Bulgarians was due to the large amount of lactic acid they absorbed in their diet of sauerkraut and soured milk products. Soon afterwards American packers were selling millions of cans of sauerkraut.

The terms "coleworts" and "collets" in old publications merely signify cabbages eaten young or before their hearts become firm.

Classification and Varieties *

A. Early. First to reach edible maturity; not a storage type; average weight of heads, 2–4 pounds.

1. Heads globular: Golden Acre, Copenhagen Market, Dwarf Round Dutch, Vienna.
2. Heads flat or drumhead (the term "drumhead" designates white, red, or savoy cabbages with heads that are broad but elliptical in cross section): Early Spring, Early June, Early Savoy, Dwarf Flat Dutch.
3. Heads pointed or conical: Jersey Wakefield, Jersey Queen.

B. Intermediate or midseason.

1. White.
   - (*a*) Heads globular: Glory of Enkhuizen, Globe, Round Dutch, Bonanza.
   - (*b*) Heads flat or drumhead: All Head Early.
   - (*c*) Heads pointed or conical: Charleston Wakefield, Winnigstadt.
2. Savoy. Leaves blistered, with little bloom: Early Dwarf Ulm.
3. Red (the color which is most common and most popular is nearly purple or reddish purple; red cabbage is attractive for salad use and of distinct quality for pickling and certain culinary preparations): Red Rock.

C. Late. Latest to reach maturity; the best storage and sauerkraut varieties; average heads 4–6 pounds in weight, often more.

1. White.
   - (*a*) Heads globular: Danish Ballhead, Ferry Hollander, Penn State Ballhead, Wisconsin Hollander, Huguenot.
   - (*b*) Heads flat or drumhead: All Seasons, Late Flat Dutch, Surehead.
2. Savoy: Improved American Savoy, Chieftain.
3. Red.
   - (*a*) Heads globular: Large Red.
   - (*b*) Heads flat or drumhead: Mammoth Rock Red.

Golden Acre is a leading early, globular cabbage. *Copenhagen Market* is slightly later and larger, as is Green Acre. *Glory of Enkhuizen* is a high-yielding, globular early-midseason variety but is none too uniform. *Bonanza,* designed for southern shippers, has hard heads and a long harvest period in the North.

* Disease-resistant strains are mentioned in Chapter 15.

Charleston Wakefield yields well when overwintered outdoors in the South. *Huguenot* is rounder-headed, somewhat hardier, bolts less, and is adapted to the South as an overwintered type.

Ferry Hollander is a late, globular, storage variety. *Wisconsin Hollander* is resistant to yellows. *Danish Ballhead,* the chief late variety for home use, market garden, storage, and sauerkraut, may be classified into short-stem, middle-stem, and tall-stem strains. The short-stem strains are somewhat earlier than the tall strains (a short stem for this variety may be long in comparison with those of other varieties). *Penn State Ballhead* corresponds to middle-stem Danish Ballhead in general appearance, but the heads are rounder. *Late Flat Dutch, All Seasons,* and *Surehead* are flattish, main-crop-to-late varieties.

Chieftain is an improved savoy. *Mammoth Rock Red* (flat) and *Round Red Dutch* (globular) are leading late, red cabbages.

O-S Cross (a breeding contribution from Japan) is probably the first cabbage hybrid to be listed; it received an All-America award for 1951.

Plant Characteristics

Most of the root system is in the upper foot of soil, and much of it runs horizontally within 2–3 inches of the surface. Before the plants are half grown the roots may cross in the centers between the rows; deep tillage would destroy many of them. Occasional roots may extend from one row across to the next.

There is produced relatively early a rosette of leaves with a distinct but not particularly conspicuous terminal bud of rather loosely overlapping young leaves. As growth progresses, a stage is reached when few more leaves are formed and the leaf area remains more or less constant. Meanwhile the terminal bud grows rapidly and becomes thick and fleshy, forming the head. A vertical cross section through the head discloses a central axis or core to which the leaves of the head are attached, and in the axil of each one is a fleshy rudimentary leaf bud. Poor heading or complete failure to head may be due to poor seed stock, e.g., crossing with other cole crops, or to a distinctly unfavorable environment. Size of head varies with the climate, weather, variety, spacing, moisture supply, and date of harvest.

Producing Cabbage

Climate

Cabbage thrives best in a cool, moist climate. Hardened young plants may tolerate 20–25°F., perhaps even 15°F., if not of long duration. But if the plants have not been hardened a light freeze may ruin them. The flavor of the savoy type, in particular, is improved by moderate frost near harvest time.

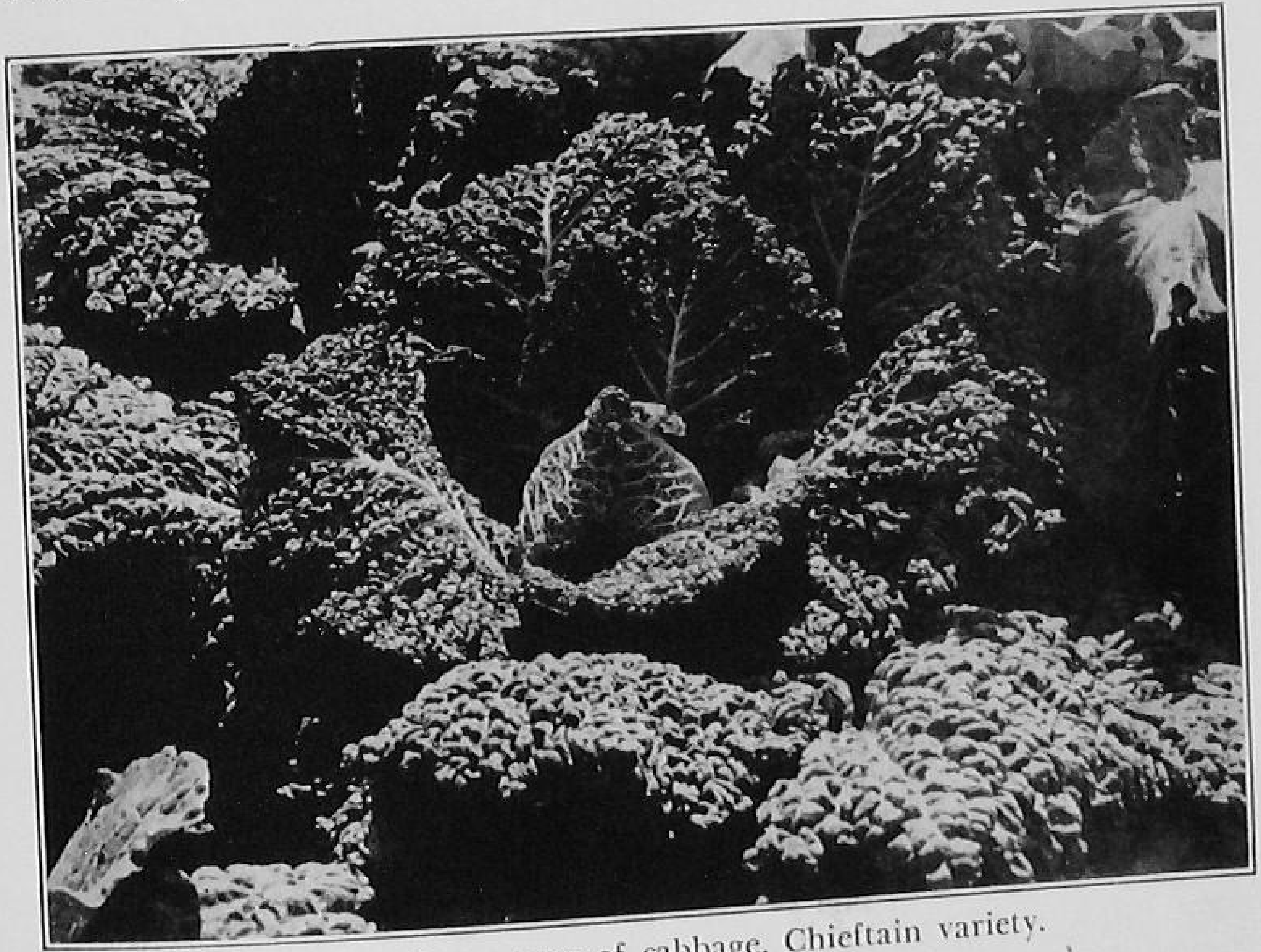

Fig. 50. Savoy type of cabbage, Chieftain variety.

The farther north and the higher the altitude, the more the outer leaves tend to be erect and the heads to be longer or deeper in proportion to diameter, though the entire plant is wider spreading. In areas with comparatively dry atmosphere, the leaves tend to be more distinctly petioled than in the more humid areas. Heavier bloom results from low soil moisture and air humidity than from humid conditions.

Methods of Starting the Plants

Flat method. One method of growing early cabbage is to sow the seed, 4–6 weeks before outdoor planting, in flats placed in a greenhouse or hotbed and prick-out the seedlings to 1–2 inches

apart each way in other flats. Pricking-out is done when the seedlings show their first true leaves, or about 2 weeks after sowing. About 1 pound of seed gives sufficient plants for 4 acres.

Frame method. The seed is sown thinly in rows 2–6 inches apart in hotbeds or coldframes and transplanted to other hotbeds or coldframes, or directly to the field. About 1 pound of seed gives enough plants for 2–3 acres.

Seeding outdoors and transplanting. In the South, and for a late crop in the North, a sheltered spot is chosen and the seed sown rather thinly (20–25 seeds per foot) in a seedbed in rows 8–18 inches apart, ¼ pound of seed being used for each acre to be set. It takes 5–8 weeks to grow the plants. The plants are thinned to ¼–½ inch apart in the rows. They are moved from the seed rows to the field, preferably when they are 5–6 inches high. Millions of cabbage plants are grown in the South for planting in northern areas.

Four methods of sowing seed are used in Louisiana: [82]

1. In *July, August, and September,* seed is sown in fields on the row. This method is adapted for sowing during hot summer weather for the fall crop. It is difficult to transplant cabbage plants during this period. On sandy land, irrigation is usually necessary to ensure a stand. On heavier, moisture-retentive soils good stands result, especially when the rainfall is well distributed. Sowing is done at intervals of 10–14 days, depending on the rainfall. Soil well wetted by previous rains or irrigation is best. Sowing should not be done on a freshly prepared seedbed. Decomposing organic matter or fermenting manure should not be incorporated in the ridge when seed is to be sown soon. At seeding time, the ridge is dragged off, exposing a packed, moist surface. The seed is drilled at the rate of 3 pounds per acre and covered shallow (not over ¼ inch). If the soil packs readily, the seed is barely covered. The soil is firmed with a roller after sowing.

2. From *July to November,* seed is sown on an open bed and transplanted to the field later. This is a good method to use if the soil for the entire crop is not prepared early and where the fields are not equipped with irrigation. Land is prepared in beds 5–6 feet wide, and the seeds are drilled by hand in rows (4–8 inches apart) running crosswise or lengthwise of the beds. Seed can also be broadcast. Water should be handy if rainfall is not adequate. A covering of brush placed on a rack and one of cotton sheeting protect the plants against sun and beating rains. These coverings also aid in holding moisture and humidity.

3. From *October to December* sowing can be done in coldframes for transplanting. This supplies reserve plants for use when occasional heavy freezes occur. The seed is sown in drills in coldframes covered with cotton sheeting. This sheeting is covered, in the event of severe weather, with a deep layer of pine straw, broom sedge, straw, or hay.

4. From *September to December* a combination of sowing methods is used for the main crop. During October the heaviest sowings for shipment to northern markets are made. Many growers sow three drills to the ridge and transplant the plants from the two outer rows. Others sow a single drill to the ridge, transplanting thinnings in late December or early January.

SEEDING IN THE FIELD. Seed may be sown directly in the rows for a late crop. When the plants are 1–2 inches high, they are thinned to the proper distance with a hoe. In Pacific Coast areas, seed may be sown in the fall for an early-spring crop. About two-thirds of the cabbage acreage in Florida is set with plants grown in seedbeds, and the rest, including almost all the crop in the Everglades, is started from seed sown in the field, the plants being thinned to a stand.

Hardening Plants

The purpose of hardening is to make the plants more frost resistant, better able to resist desiccation from hot drying winds and the sun, and less subject to wind whipping. It is accomplished by gradually subjecting the seedlings to lower temperatures, by watering sparingly for 7–10 days before setting in the field, or by both methods.

There is an increase in amino acid content in hardened plants as a result of the breaking down of proteins to forms less easily precipitated by the increase in H-ion and salt concentrations. Hardening is accompanied by decreases in growth rate, transpiration rate per unit of leaf area, and starch, and by increases in waxy covering on the leaves, percentage of dry matter, and percentage of reducing and total sugars.

Of the vegetables that are commonly transplanted, cabbage represents the potentially hardy type that acquires considerable resistance to cold through hardening. Tomatoes represent the opposite type (see Chapter 12).

If late cabbage plants are grown in outdoor beds the temperature, and often the water, cannot be regulated. One good way to "harden" such plants is to fertilize them with potash. The greater activity of the potash ion in the soil solution may balance or inhibit somewhat the uptake of nitrogen and produce plants with stiffer stems and higher carbohydrate content that will stand transplanting better.

An extensive grower of field-grown cabbage plants asked advice as to how he could salvage several million cabbage plants that he feared would soon become too large and soft for transplanting before his customers would be ready for them. His predicament was this. His plants were growing in an extensive outdoor bed. The early part of the season had been unusually cold and rainy. As a result the plants grew very slowly, and he feared the nitrates had been leached from the soil. Consequently he applied a heavy sidedressing of nitrate of soda. Shortly thereafter the weather became unseasonably warm and his plants grew very rapidly but were making such a soft succulent growth they would not be satisfactory for transplanting.

He was advised to apply a sidedressing of muriate of potash to his cabbage plants to "harden" them. In order to get a more prompt response, since time was an essential factor, he was advised to apply the potash in solution. Since he was equipped with a large mounted tank with tubes to apply calomel solution to his cabbage plant rows to control cabbage maggot, it was suggested that he use this equipment to apply the muriate of potash in solution directly on his cabbage rows. This was applied at the rate of 60% muriate of potash per 50 gallons of water, using 750 gallons per acre.

The result was that very satisfactory plants were produced by this treatment. The plants receiving the potash sidedressing made a stockier growth with firm stiff stems that stood transplanting well, whereas untreated plants made such a rank soft growth they were discarded. Similarly, plants in the field, if they are making too soft and rank a vegetative growth, can be hardened by applying potash fertilizer. If too much potash is applied an apparent nitrogen deficiency may occur.[331]

Planting Outdoors

Well-hardened plants for the early crop may be set out as early in spring as danger of hard frost is over. "Starter" solutions may be helpful.

In the South, cabbage is set in the fall to grow and mature in early spring. Level culture is usual, but ridges or raised beds are necessary for irrigation, and where plants are set in the fall it is wise to make a ridge, east and west, and to plant on the south side, thus taking advantage of both sunshine and shelter from cold winds. The plants are set deep enough so that the first leaves almost touch the ground.

In small plantings, cabbage plants may be set with a trowel. In larger plantings, a furrow may be made about 3 inches deep. Machine transplanters save time and labor on large acreages, and they open the furrow, apply water around the roots, and pack the soil around the plant, all in one operation. Later cultivation fills in the furrow and provides some support to the lengthening stem.

Spacing

Relatively wide spacing promotes earliness, and larger, heavier heads. Yield per acre and number of heads harvested usually are increased by close spacing. Where medium-sized heads are desired the spacing is a little closer than for large heads. Close planting tends to cause the outer leaves to be shorter and more incurved or spoon shaped, so that the plants have a more rosette-like appearance than is typical.

Early cabbage is usually set 16–18 inches apart in the row; small varieties like Jersey Wakefield may be set 12–15 inches apart; and larger kinds, such as Succession and Copenhagen Market, 18–20 inches apart. Danish Ballhead, the chief late variety, is usually planted 20–22 inches apart, and Flat Dutch 24–26 inches apart, in the row. The spacing between rows is commonly 28 inches for horse cultivation, and 34–36 inches for tractor equipment.

Soil, Manure, and Fertilizer

Cabbage thrives well on most soils of reasonably good fertility, texture, and moistness. It is a gross feeder and is a rather hard crop on the soil. Both well-rotted manure and fertilizer may be liberally used to advantage.

Soil reaction and club-root. The soil is often limed as a preventive, in part, of club-root. This disease is usually damaging only on acid soils. If clover will not thrive well the soil should be limed for cabbage. On muck, cabbage produces fairly well down to *p*H 4.6, if copper sulfate (5 percent in fertilizer) is applied.

Soil type and maturity. For early cabbage, a soil that is warm early in the season should be chosen. It should be a sandy loam retentive of moisture, but well drained, for, although abundant moisture is desirable, cabbage will not thrive if the drainage is poor. For late cabbage, which needs a longer season, heavier and cooler soils are suitable.

Manure. There do not seem to be reports of anyone who has used too much well-rotted manure on cabbage. Only well-rotted manure should be put on, in the spring just before planting.

Fertilizer. The head is composed chiefly of leaves. Large, well-developed leaves are important in order to form a good

head, and a ready supply of nitrogen is necessary. But excessive nitrogen feeding without suitable amounts and balance of other elements may promote spongy heads. For the early crop a side-dressing of nitrogen after the plants are half grown may increase the size of heads.

There is a correlation between nitrate nitrogen in Bladen fine sandy loam just prior to harvest and the marketable yield.[394] The critical point in nitrate content of the soil at this time is about 15 pounds of nitrate nitrogen per acre. Above this value the response to larger amounts of nitrate drops rapidly.

In Louisiana,[82] on a 3½-foot row basis, 600–800 pounds of 4-12-4 per acre, in a drill beneath the ridge, are applied when the land is prepared 10 days to 2 weeks before planting. Two top-dressings of nitrate of soda are given at the rate of 100 pounds per acre for each application during the growing period. One is applied when the largest leaves are 2½–3 inches wide, the other when the leaves are about 5 inches wide.

Storage varieties usually respond well to phosphorus applied when preparing the soil for planting. Manure plus superphosphate may give better results than manure alone. Cabbage probably takes up several times as much sulfur as phosphorus from the soil. In certain areas, therefore, application of flowers of sulfur to the land are beneficial (the *p*H should not be made so acid as to promote club-root). Sulfur compounds account for the offensive odors from decaying cabbage.

When fertilizer is applied before planting, the plow-sole method may give best results, especially on the heavier soils. Broadcast and band methods are common. In any case, fertilizer must not be placed in direct contact with the seed.

When boron is deficient the tissue in the center of the stem or core becomes dark brown and resembles decay. In Mississippi,[56] the percentage of deficient plants was reduced from 30 percent on plots receiving no borax and no lime to 11 percent on plots with 20 pounds of borax per acre. With increased amounts of lime (soil *p*H 6.2–7.2) the number of deficient plants was greater, and borax did not reduce the deficiency as much as it did in plots without lime. Therefore, some of the boron which was added or already present was made unavailable to

the plants by heavy liming. No bad effects showed on cabbage grown in plots receiving 20 pounds of borax per acre for 4 successive years.

Irrigation

Cabbage transplants are generally irrigated first soon after they are set in the field, unless adequate soil moisture is present then. But a light application usually helps the plants re-establish themselves rapidly. About three further irrigations are given to late cabbage and two to early cabbage. An additional one may be needed on a sandy soil. If cabbage is irrigated heavily when the heads are well developed and quite firm, many of them may split within 24 hours.

The water is run through furrows rather rapidly until the soil has been wetted. Then the stream is reduced to a trickle and run slowly for ½–¾ hour or until the soil is soaked. If a shovel is easily pushed down to blade depth without striking solid ground, the soil has been properly irrigated. In well-irrigated soil the cabbage plants are generally so loose for 6–8 hours after the water has stopped running that they could easily be pulled up by hand. But if they are solid and immovable after watering, another irrigation will soon be necessary.

The annual rainfall in Florida averages about 52 inches, which would be adequate for most vegetables if it were spread uniformly over the year. But most of the rainfall occurs from June to September. Thus, during the time when most of the Florida vegetables are grown, rainfall is generally light and irregular, and so most of the commercial acreage is on soils where the moisture is often increased by irrigation. Irrigation encourages high yields in years of near normal rainfall as well as in drier years.[287] Sidedressings of cabbage with nitrogen as nitrate of soda are more effective in increasing yields during years with near normal rainfall.

Cultivation

Ample space is needed between rows at planting time for subsequent cultivation for weed control. Deep cultivation may do more harm than good by destroying the roots near the surface.

Burst or Split Heads

The heads often burst or split when rain follows a dry period, because of the new growth caused by the increased moisture. A preventative, in part, is to check growth by deep cultivation, or by twisting, loosening, or slightly lifting the plants. Another remedy is to push a spade down at one side a foot or so from the plant and then to heave the spade somewhat to break some of the roots so as to cause a reduction in intake of soil moisture.

Premature Seedstems

If the crop is sown in autumn and grown through the winter, cabbage may develop seedstems before the plants head. Growing fall-set plants at relatively low temperature is essential to bolting, but other factors have an influence on it. The earlier the seed is sown, the higher is the percentage of bolters, because early plants are the largest when exposed to low temperature. Increasing the size of plant by fertilizing the plant beds increases the percentage of bolters, but fertilizer treatment in the field has no such effect. A critical stage is when the largest leaves are 3–4 inches wide and the plants are exposed to 40–60°F. Strains of Wakefield that produce small, compact heads and that head uniformly are less likely to bolt than those that are somewhat openheaded, leafy, and late maturing. Thus, bolting is partly hereditary, but environmental conditions determine the expression of the hereditary tendencies.

Harvesting

Harvesting early cabbage usually begins when the heads are large and firm enough for use.

Later cabbage is not harvested until the heads are full and hard, or until the green cover leaves begin to curl back slightly, exposing the whiter leaves beneath, at which stage the cabbage is about as hard and heavy as it will become without bursting and without being too crisp and brittle for good handling. Late cabbage may be left in the field until danger of severe frost. If freezing extends into the head, cutting should be stopped for a time. If favorable weather follows, the heads will thaw, and may show no sign of injury when the outer leaves are trimmed off.

The head is grasped in one hand, bent slightly, and cut off with a heavy knife. In some sections a long-handled, spade-like knife or "spud" is used for ease and speed, but many of the heads may be cut either with too long a stem or with part of the base chopped off.[364] Stems should be ¼–½ inch long.

Southern new cabbage is usually shipped with 4–7 green wrapper leaves attached. Late-crop cabbage is usually trimmed to 4 or less closely fitting wrapper leaves. Any leaves showing material damage from worms, disease, or other cause should be removed even though this means close trimming.

Containers

Much cabbage is shipped in light green, open-mesh, 50-pound sacks. Wooden containers are usually the 85–100 pound Los Angeles crate (13 × 18 × 21⅝ inches, inside), the 45-pound half crate (9 × 13 × 21⅝ inches, inside), 45–50 pound 1½ bushel hamper, the Howard crate (10 × 16 × 22 inches or 13 × 13 × 22½ inches, inside), the 50-pound corn or melon crate (12 × 12 × 22 inches), second-hand wire-bound citrus boxes, and bushel baskets.

Cabbage packed in crates should be arranged in orderly layers with stems out. The heads should be pressed firmly but carefully into position so as to make a tight pack. Crushing and excessive bruising should be avoided. The crate should be well filled so that the cover slats will show a slight bulge, thus preventing damage from shifting of the contents.

Storage

Late varieties usually store better than early ones. Danish Ballhead is outstanding for storage; under good conditions it will keep 3–4 months and has been known to keep well for 6–7 months.

If cabbage is to keep well it must be firm, mature, not too ripe, and harvested before it experiences many heavy frosts. Immature heads rot or produce second growth quickly in storage. Usually late cabbage is left in the field until shortly before freezing weather. The heads should be handled carefully to avoid bruising and subsequent rot. Only those that are free from bad insect injury and diseases like black rot and soft rot should be stored.

The best storage temperature is 32°F. A relative humidity of 90–95 percent will keep the leaves fresh and turgid; good air circulation will avoid condensation if a uniform 32°F. storage temperature is maintained.

For piling for late-fall or temporary storage the ground is leveled in a place where water will not lie, or a sod site is selected and the cabbage is placed in piles of various widths up to about 8 feet. A convenient pile has a bottom layer 3 cabbages wide, a second layer 2 cabbages wide, and so on, in a long row, all with tops down and roots cut off. These are covered with straw until there is danger of freezing. Soil is added when the weather becomes more severe, but should not be put on too early, for fear of heating. It is impossible to control the temperature and humidity completely in an outdoor storage; also, removal of the cabbage from a pile may be inconvenient.

Insect and Disease Control

Cabbage root maggot fly lays elongate, white eggs in the soil near the stems or on the roots. White maggots hatch from these eggs, attack the rootlets, and then burrow into the main root, causing the plant to wilt or die. Corrosive sublimate (1-1,000) applied to plants in the seedbed or in rows at the rate of 1 gallon to 35 feet of row and ½ cupful per plant 3–4 days after the plants are set and twice again at weekly intervals is a fair control. Lindane is even more effective.

Stretching cheesecloth across the frame and fastening it tightly on three sides prevents eggs being deposited in the seedbed. The fourth side is fastened with a wooden strip nailed loosely to permit weeding and thinning. The cloth is removed at least 2 weeks before the plants are set out.

Tar-paper discs placed around the stems of newly set plants immediately after planting prevent the fly from depositing eggs there. The disc must rest on the soil surface and must not be covered with soil.

Cabbage caterpillars include the imported cabbage worm, cabbage looper, and diamondback moth. The caterpillars eat holes in the leaves and finally tunnel into the heads, where they leave a dirty excrescence. Dusting with DDT before the heads form and with rotenone or pyrethrum after the heads form gives good

control. The waxy bloom on the leaves is a drawback to adherence of sprays or dusts.

Harlequin cabbage bug is shield shaped, black, mottled with red or yellow, and 3/8 inch long. It is a sap-sucking insect. Controls are hand-picking the bugs and egg masses and dusting with sabadilla.

Cabbage aphid is greenish, powdery, soft bodied, and small; it occurs in clusters. The leaves become distorted and curled. The plants become stunted and may die. Controls are: dipping infested plants in nicotine solution; dusting with nicotine when the air is still and 70°F. or above. A dusting curtain, 25 or more feet long, is helpful.

Flea beetles eat small holes in the leaves and are especially damaging to young plants. DDT or rotenone dust is the control.

For *damping-off* see Table 5 and footnote under Copper Oxide in Chapter 15. For *root knot* (eelworm or nematode) see footnote under DD in Chapter 15.

Club-root (slime mold) shows as malformed and greatly enlarged roots. The plants are stunted, sickly, and wilt on hot days. Seed and plants should be set in disease-free soil. In mildly infested soil lime should be applied just before planting. Mixing a small quantity of calomel and some lime in the seedbed soil may be helpful.

Blackleg symptoms are ash-gray spots on the leaves and stems and a dark-colored area at the base of the stem. The fibrous roots decay, and this causes a stunting and wilting or dying of the plant. Seed treatment with hot water (122°F.) for 20 minutes is effective but reduces the germination. Corrosive sublimate treatment kills the fungus on the surface of the seed, but not the fungus threads (mycelium) that may be within the seed. Diseased plants should be burned. A 4-year rotation is helpful.

Black rot (bacterial wilt) symptoms are: leaves with black veins, leaves that turn yellow and drop, and black ring of dead vascular bundles in the stem. Cabbage heads may decay and drop in a foul mass owing to secondary soft-rot infection. Rotation should be practiced in the seedbed and field, and the seed treated as for blackleg. Seed from Pacific Coast regions is free from black rot.

Yellows or Fusarium wilt affected plants are stunted, turn yellow, and drop their leaves from the ground up. Cut stems show

a brown discoloration of the vascular system. The parasite may remain in the soil for many years. In yellows-resistant types developed by Dr. J. C. Walker, University of Wisconsin, "Improved" in front of the variety name means that besides being resistant to yellows these stocks are also highly resistant to mosaic. Resistant cabbage strains are: Wisconsin Golden Acre, Racine Market, Resistant Detroit, Marion Market, Iacope, Jersey Queen, All Head Select, Improved Wisconsin All Seasons, Globe, Improved Wisconsin Ballhead, Wisconsin Hollander, Bugner, and Red Hollander.

Seed treatment (see Table 5) is helpful as a disinfectant and protectant.

CAULIFLOWER AND HEADING BROCCOLI

Cauliflower is more difficult to grow successfully than cabbage. In the seedbed, the seedlings often suffer from damping-off. In the garden, the plants may fail to form desirable heads if the weather is dry and hot. A hard frost, and low soil or air temperature, may stunt the growth early in the season, thus causing the heads to develop prematurely and "bolt" or "button." Poor seed is a frequent cause of failure. Moderately cool weather and a uniformly good supply of soil moisture are essential. There must not be a check at any time during the growing period. The leading areas are the maritime climates of the Pacific Coast and Long Island, the foggy-night Catskills, western Maryland, Colorado, and near the Great Lakes.

Late-type cauliflower, commonly called heading broccoli, is not well adapted to northern regions. It is much grown in California and other places on the Pacific Coast for shipment and local use in winter.

History

The cauliflower (named from the Latin *caulis,* cabbage, and *floris,* flower) probably originated in Cyprus, the south of Italy, or some other part of southern Europe on the Mediterranean. Dodoens, in 1554, illustrated a crude cauliflower and said: "The seeds came from Cyprus, because they would not ripen well elsewhere, being too sensitive to the cold." Miller, in 1731, said that the cauliflower was not brought to any degree of perfection in

English gardens till about 1660 and that "the White Broccoli approaches so nearly to the Cauliflower as to be with difficulty distinguished from it."

Vilmorin, a famous French seedsman, said: "The sprouting or Asparagus Broccoli represents the first form exhibited by the new vegetable when it ceased to be the earliest Cabbage, and was grown with a special view to its shoots. After this, by continued selection, and successive improvements, varieties were obtained which produced a compact white head."

The Erfurt cauliflower, with its many allied forms known as Snowball and by other names, is an old type, and was known at Erfurt, Germany, about 1660.[130] It is smaller than the Mediterranean types, has smaller and shorter leaves, and is usually more glaucous green. The types of cauliflower from India are still smaller and earlier than Erfurt. Still other types have been developed in France.

Most of the improvements in cauliflower in the last hundred years have been made in Denmark. But since 1942, the Ferry-Morse Seed Co., San Francisco, Calif., has introduced a number of new varieties from seed produced in the United States.

Varieties

Seedsmen usually list fewer varieties of cauliflower than of a number of other vegetables. It is not easy to distinguish between varieties. Differences between strains of a certain variety are often as great as, or greater than, differences between two so-called varieties. Persistent endeavor should be made to secure seed of a well-bred and well-selected strain, for perhaps no other single factor affects successful culture as much as this one.

Early Varieties

In northern areas, early varieties planted late usually produce a later and better crop than late varieties planted early. If seed is sown periodically, early-type varieties will provide heads for early, midseason, and late use.

Erfurt has long been a leader for home and market gardens. The name has largely been supplanted on this continent by *Snowball,* which is probably the most widely grown type in northern regions. *Super Snowball* is a larger strain but is not deep.

Early Snowball "A" is an early-maturing strain from American-grown seed. *Snowdrift* is somewhat more vigorous than the earlier kinds. *Snowball "X"* is an American-grown strain of Snowdrift main-crop type. *Snowball "Y"* is slightly later. *Snowball "M"* is earlier than "X," but later than "A," and somewhat smaller in growth than "X." *Codania* and *Perfection* are strains of Snowball from Canadian-grown seed stocks. *Ideal Snowball* (All-America, 1949) was bred in Switzerland.

Late Varieties

The late varieties (including heading broccoli) are larger growing and are not so well adapted to usual culture in northern areas as the earlier sorts. They are "a little too long in the leg"; i.e., the head is produced rather high off the ground on a long stem. *Autumn Giant* and *Large Algiers* are two of the older late cauliflowers. The following strains, developed by Ferry-Morse Seed Co., extend the season in California from November to May and provide most of the shipments from California in winter: *November, Christmas, February, March Early, March Late, April, Late Pearl, Mission Special,* and *St. Valentine.*

Plant Characteristics

Leaves

The leaves of cauliflower are usually longer and narrower than those of cabbage. The small inner leaves are at first incurving and protect the curd for a time. The leaves of the late type become larger and longer than those of the early type and protect the head better.

Head or Curd

The edible portion, or curd, which is made up of numerous, much-divided, hypertrophied branches, terminates the main stem. When the head is in its prime for cutting, there is no trace of floral organs.

A *ricey head* is caused by elongation of the peduncles which bear the individual flower buds. The curd becomes granular and loose. A ricey curd is not so objectionable as a badly spread one, but it is very undesirable; a badly spread curd is not necessarily ricey. Good seed and culture under favorable conditions

tend to avoid ricey heads. Warm weather at harvest time and allowing the curds to become slightly overmature promote riciness.

A *fuzzy head,* which is velvety in appearance, occurs when the flower pedicels elongate. It often results when plants are grown under unfavorable conditions, when the heads become slightly overmature, and because of hereditary factors. Preventive measures are much the same as those that avoid ricey heads.

In a *leafy head,* small green leaves grow between the segments of the curd. It appears in either poor or good strains of seed, but mostly when growing conditions are unfavorable.

"Buttoning"

"Button" plants are characterized by small exposed heads that appear shortly after field setting, at a time when normal plants of the same age appear to consist entirely of vegetative growth. Buttoned plants are of no market value.

Button losses [63] are usually confined to the early-planted crop and are more severe in cold, wet seasons. Exposing plants to low or below freezing temperatures does not alone cause buttoning. Holding plants in flats beyond their best transplanting condition increases the tendency to button. Plants set in the field when young (4–6 weeks old) do not button if grown later under conditions favoring vigorous growth. Retarding the development of older plants in flats by exposure to low temperature or withholding soil moisture decreases the amount of buttoning. Low soil nitrogen increases buttoning, owing to less vegetative growth. Severely stunting plants by low temperature or low moisture does not result in buttoning, and so not all checks in growth will cause it. Exposing plants to 40–50°F. for 2 weeks hastens head formation in contrast to plants grown at 70–80°F., a temperature too high for normal initiation. Low spots and areas of shallow topsoil may, owing to nutrient deficiency, retard vegetative growth and foster earlier appearance of the head.

Seed

The importance of good seeds needs emphasis. Poor strains may not produce good marketable heads even under the best conditions. The price of good cauliflower seed is high, but it is much more costly to sow inferior seed.

Producing Cauliflower

CLIMATE AND WEATHER

Cauliflower thrives best in a cool, moist climate. It will not stand so much cold as cabbage. If set out very early it must be well hardened previously. Low air or soil temperatures during early stages may stunt the plants. High temperature when the curds are maturing promotes defective heads and may cause such rapid growth of the curd that it is difficult to harvest in the best stage of development. Dry, hot weather may prevent heading or result in small, hard heads. There must be enough moisture in the soil to ensure steady growth; well-regulated irrigation often encourages good results.

Late in the growing period it is desirable that the temperature be cool and uniform and that fairly moist conditions prevail. Early-type cauliflower when planted late matures nicely in early fall in most years and finds favor with the housewives who do much of their pickling at that time of year. But temperatures below the optimum delay maturity, reduce size, and so lower the yield.

Full-grown heads are more subject to damage by fall frost than small ones, and exposed ones more than those that are tied up. Tied-up heads will tolerate 20–25°F., provided that it is not long continued.

SOIL

Soil for cauliflower should be fertile, in good physical condition (well supplied with humus), and retentive of moisture. For the early crop a soil that warms up rapidly and has the foregoing essentials is ideal. Many failures are due to delayed spring plowing. It is wise to plow in the fall and thus help conserve the moisture supply.

Cauliflower grows best on a neutral to slightly acid soil, i.e., *p*H 6.0–6.8. Cauliflower or any of its *Brassica* relatives (cabbage, Brussels sprouts, turnips, kale, mustard, collards, or rutabagas) should not be grown on the same soil more than once in 4 years or serious disease infection may result.

Manure and Fertilizer

A liberal quantity of manure, turned under the fall before planting, is highly desirable. Well-rotted manure can be used with great freedom as a fertilizer for cauliflower.

A deficiency of nitrogen may result in "buttoning" (see earlier). Cauliflower often responds well to phosphorus, as in superphosphate, applied when preparing the soil for planting in spring. It is not wise to place this or other fertilizers directly underneath the plants when setting them out. In early stages of potassium deficiency, yellow mottling is restricted to the apical margins of the older leaves. If chlorosis envelops the entire leaf, the margins become brown and curled under by the time the yellow mottling has spread to the central and basal portions.

In "browning," which is caused by a deficiency of boron, discoloration appears as small, concentric, watersoaked areas in the stem and in the center of the small branches of the curd. The edges of the leaves are red or purple with a light-green or orange band extending inward from the periphery of the leaf. There is also a stunting and deformation of the leaves nearest the curd. The curds are smaller, incompletely developed, brown, and bitter. Browning is usually associated with hollow stem, but hollow stem may occur independently. When browning is severe, the outer, as well as the inner, portion of the head is involved. Rusty-brown areas (brown rot, red rot) may appear on the surface of the curd as another stage of the trouble. About 6 pounds per acre of borax is an effective control.

Chlorosis due to magnesium deficiency shows as a yellow mottling between the veins of the lower, older leaves. In wet weather the leaves become skeletonized, and in dry weather the interveinal areas become dry and tan colored. When affected leaves remain intact they become bronze colored and stiff, yet are normal in shape. Abscission of the lower leaves occurs and results in a smaller head. This chlorosis is avoided by using about 300 pounds of magnesium oxide per acre. Even if magnesium deficiency symptoms are not visible, increases in the number and weight of salable heads may result from application of dolomitic hydrated lime on certain soils.

Whiptail (strap-like leaves) is due to a deficiency of molybdenum. It can be corrected [302] on neutral soils by applying 2–4

pounds of sodium molybdate per acre. Molybdate sprays may also be helpful. Liming is also a corrective as it raises the soil *p*H and increases the availability of molybdenum in the soil.

Starting the Plants

Seed for early cauliflower is sown slightly later than for early cabbage. The usual practice in northern areas is to plant early enough so that heads form before the heat of midsummer, and to start the late crop so that heading begins in the cool weather of early fall. Cauliflower seed is sown 5–7 weeks before transplanting outdoors. Several seedings at 2-week intervals extend the season. Cauliflower is seeded broadcast in flats, or in rows 2 inches apart in flats, benches, or beds, in forcing structures, at the rate of 8–10 seeds per inch. Thickly grown plants are likely to suffer from damping-off. The late crop is commonly drilled in beds.

About 4 ounces of seed will provide ample good plants for an acre of crop. For larger acreages, about 4 pounds of seed is required per seedbed acre. One acre of plant bed will set out about 20 acres.

Seedbed soil for cauliflower need be only moderately rich but should not be poor. In too rich a soil, the young plants may become spindly or leggy and do not transplant so well as stocky ones which have grown at a moderate rate. Plants that have been stunted by remaining in flats or seedbeds too long, and those that are in poor soil, may head prematurely. Greater care must be taken with cauliflower in the hotbed than with cabbage, as its seedlings damp-off more easily. (See also under Cabbage, Methods of Starting the Plants.)

Seeding in the field is the usual practice in parts of California and Arizona, and the thinning and seed costs are less than the costs of growing and transplanting. About 1–2 pounds of seed are sown per acre, between August 10 and September 15.

Transplanting Outdoors

In planting care is needed to prevent any serious check to growth. A sudden check from wilting due to hot weather, dry soil, or other cause will adversely affect head development. Plants for the earliest crop are usually set out as soon as danger of hard frost is over (often chanced earlier) and the soil has

warmed somewhat. Plants of successive sowings are set out at 2-week intervals.

Cauliflower plants when set out should be just large enough to handle easily. The larger or more "leggy" they are when planted, the greater is the likelihood of their becoming stunted, bolting, or forming small heads. A check, even a slight one, in the early stages of seedling or plant growth may result in poor development later which perhaps may erroneously be ascribed to other causes. Applying water immediately after planting is usually helpful, especially in warm, sunny weather when the plants soon droop. "Starter" solutions are of no more benefit than water unless the elements supplied are quite deficient in the soil. If possible, a cloudy day or a time just before or after a rain should be chosen for planting, or, if the weather is hot and dry, the plants should be set out in late afternoon and evening.

Spacing the Plants

Good spacing is 15–18 inches for early strains and 18–24 inches for late strains, with 2½–3 feet between rows.

Irrigation

A good plan in irrigated areas is to make a moderately wide, shallow furrow, to set the plants in the center of it, and to direct the water into the furrow among the plants long enough to soak down to the level of soil moisture. When the heads begin to form, weekly irrigating may be wise. At first, a good volume of water is run through shallow ditches made between the rows, without overflowing and causing puddling around the plants. When the water reaches the ends of the rows the stream is reduced to a trickle, which is run for 4–5 hours on heavy soil and 2–3 hours on sandy soil.

Cultivation

Frequent shallow cultivations that kill young weeds help to conserve soil moisture. But deep and untimely cultivation destroys many feeding roots, loosens the soil so that moisture escapes, and hence does more harm than good. Cultivation should begin soon after the plants are set, in order to keep ahead of weeds. If comparatively late cultivation is done during the

heat of the day, when the leaves are limp and bend readily, there should not be much breakage, but it is not wise to cultivate after the plants have begun to head, especially if the dust would discolor the heads or if the roots would be seriously damaged. At the last cultivation before harvesting, the soil is sometimes worked up to the stems a little to reduce wind damage, but this practice may cause more damage by the cultivator, as he works close to the plants, than is gained by hilling.

Blanching the Heads

A prime index of quality in cauliflower is not so much the solid, compact character, though this is very important, as the whiteness of heads. Blemishes due to sun, rain, frost, soil, insects, diseases, and sprays or dust materials cause the heads to become brownish. Such heads are not attractive in appearance or flavor.

One method used to blanch early varieties is to draw the outer leaves over the head and tie them near the tip or above the flower head, in tent form, with soft but strong string, raffia, rubber band, or other material. Usually the best time to tie up is when the leaves, which cover the head very closely, begin breaking away and expose the young curd. Too early tying will often prevent or constrict the development of the heads, and too late tying may fail to blanch them.

The leaves are usually tied up fairly tight, but if they are left slightly open (just so the sun will not spot the heads), the heads can be inspected for cutting condition. If danger from frost threatens the late crop, the leaves are tied closely to protect the heads. The planting is gone over at intervals, because all heads are not ready at once. Heads may be tied with twine of different colors each day the planting is gone over, to help the grower distinguish between heads tied up on different days and between those at different stages of development. A man can tie 800 heads a day.

In hot weather, when the plants are growing rapidly, 4–5 days may be enough for blanching; in cool weather 8–12 days may be needed. If the heads are left tied too long in hot weather, the leaves begin to rot and discolor the head. In cool weather, the heads begin to bolt and become ricey or begin to branch if left too long.

Another method is to break the midrib of the leaves, bend them over, and tuck the tips down around the head. The inner leaves are broken over first and the outer last. The leaves should be left intact and not torn off so that they wilt and shrivel. If

FIG. 51. Cauliflower plant tied for blanching and protection of the head.

the midrib is broken, the leaves remain fresh a reasonably long time and provide good protection for the head, and they seem to give way without uncovering as the head grows.

Still another method of blanching is to insert small paper plates over the heads under the curled leaves.

In the large growing areas of California and Arizona little or no tying is done.

Harvesting

The heads are harvested when they attain proper condition, i.e., before they become ricey, discolored, or otherwise blemished. They do not develop uniformly, and so a number of cuttings are necessary. It is better to cut a little too early than too late.

Compact heads 5–6 inches in diameter are desirable for market, but it is better to harvest at the correct stage of maturity than according to a size index; i.e., one should largely disregard size of head and consider only its condition. If the plants have not made a good growth, the curds will not grow, regardless of how long they remain in the field. When the head is left uncut too long, the flowerstalks elongate, and loose, leafy, ricey, or fuzzy heads result. The longer the heads are left after reaching their prime condition for cutting, the sooner they appear "old" after harvest. If some heads in the planting become overmature, it is best to accept the loss and continue to cut only the desirable ones. An overmature head in a container offered for sale may spoil the appearance of the entire lot. Overmature curds are very conspicuous, because the advanced growth spreads the leaves and exposes the curd more than is normal for heads in the best harvesting stage. If the curd is slightly spread at harvest time, this condition becomes more pronounced in handling.

The head is cut off with a large, sharp knife, with several large leaves adhering, and these are trimmed to allow only enough jacket leaves for protection. A cut is made squarely across the leaves, leaving ½–1 inch projecting above the head. The fringe of cut leaves thus left around the head contributes to an attractive appearance, shields the head from handling injury, and protects it from dirt and blemishes.

Cauliflower is easily damaged and must be handled with care. It should go to market in a fresh, pure-white condition. The heads may be cut, trimmed, and packed in the field as harvesting proceeds, or they may be cut below the bottom leaf and taken to a central place to trim and pack.

Containers

The standard California crate (8½ × 18 × 21⅝ inches, inside) is usually packed with 8–15 heads as normally trimmed. The

Long Island crate measures 13 × 15⅛ × 23 inches, inside, and is usually wire bound. The Catskill crate measures 14 × 12 × 22 inches, inside.

STORAGE

If subjected to high temperatures after cutting, the jacket leaves may turn yellow and drop off in transit or after the heads reach their destination. After 1 week at 45°F., most outer leaves are yellow and loose, and in 2 weeks, or less, they drop. At 41°F., the yellowing is slower; at 32°F., it may just have begun at the end of the month. Successful storage depends on preventing decay, retarding maturity, avoiding yellowish or ricey curds, retaining leaves and keeping them from becoming yellowish, and avoiding freezing which causes a gray-brown discoloration and softening of the curd accompanied by a watersoaked condition. The relative humidity should be 90–95 percent. The average freezing point is 30.1°F.

Sound cauliflower may keep longer than usual in storage if the heads are sprayed with naphthaleneacetic acid ("sprout inhibitor") after it is mixed with alcohol and diluted with water. A pound of the acid will treat 9,000 heads. It may be possible to treat the liner of the crate or the ice in which cauliflower is packed for shipment.

Insect and Disease Control

Whiptail and browning have been discussed earlier in this chapter. See also under Cabbage.

SPROUTING BROCCOLI

"Broccoli" is an Italian word from the Latin *brachium* meaning an arm or branch. In sprouting broccoli, a main head is produced terminally on a fleshy, branching, elongated stem. Besides the terminal head, longer, more slender, and smaller heads appear laterally in the axils of the leaves. There are three classes of sprouting broccoli, namely, green, white, and purple, but the green type is most popular. Sprouting broccoli provides a high-quality, distinctive crop. It is in demand in the high-class dining places, and is well adapted to commercial quick freezing.

Classification and Varieties

A. Very early: DeCicco, Texas Early, Calabrese (Italian Green Sprouting), Propageno, Freezers.
B. Early: Green Sprouting Early.
C. Midseason: Green Sprouting Medium.
D. Late: Green Sprouting Late.

DeCicco, Propageno, Calabrese, and *Freezers' Sprouting Green* are early types for the East and Midwest. *Texas Early* plant is

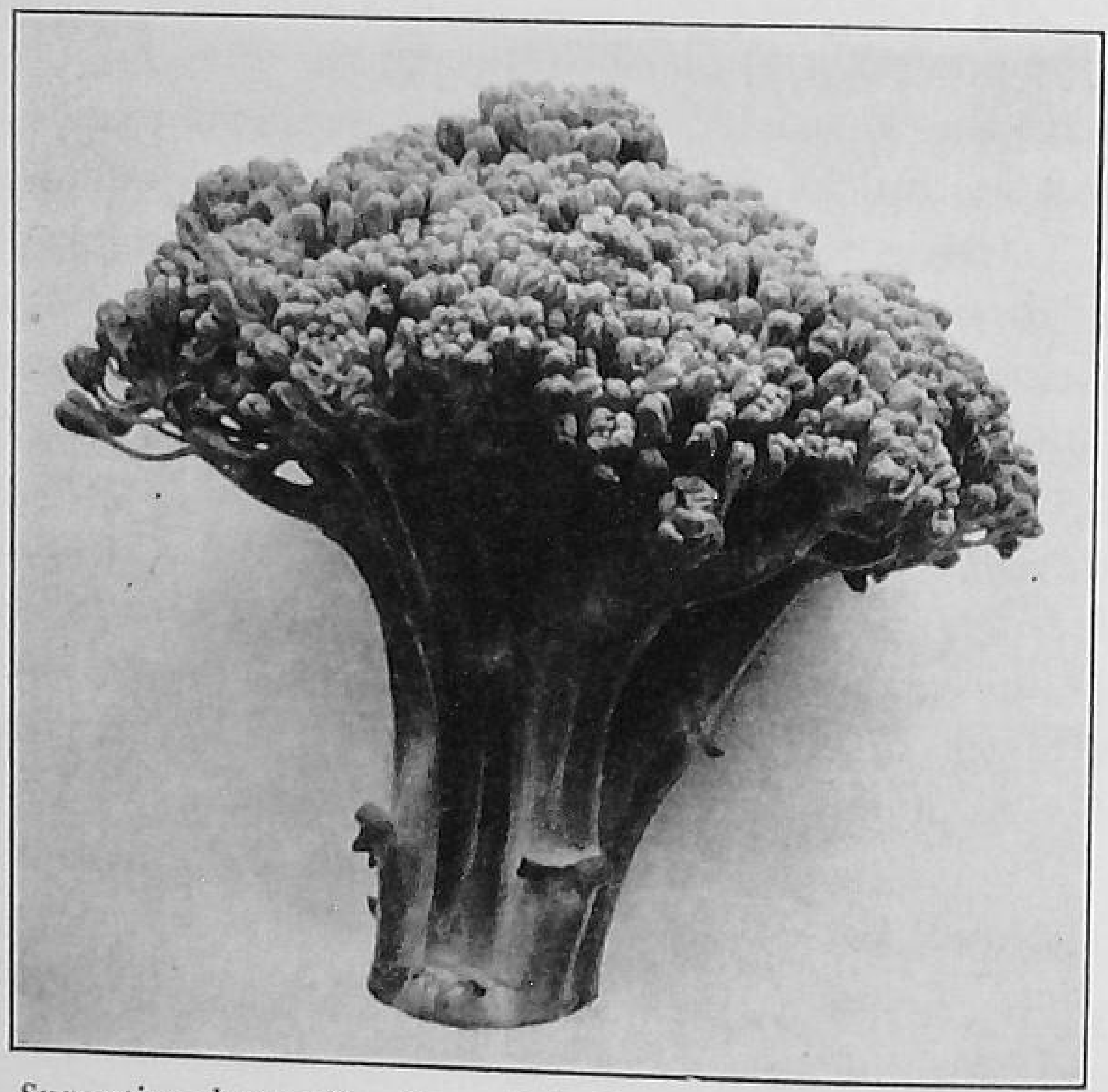

FIG. 52. Sprouting broccoli. Several inches of stem are included with the head when harvested.

small, but it produces large, firm, small-budded heads. *Green Sprouting Early* requires 70–75 days before it is ready for use. *Green Sprouting Medium* is about 3 weeks later, and, where it succeeds, it forms splendid heads and a prolific crop of laterals but is too late for most eastern conditions. *Green Sprouting Late* produces few side shoots, and is planted in fall for early spring cutting in California and along the South Atlantic coast. *Waltham 11* and *Waltham 29* have found some favor in New England.

Producing Sprouting Broccoli

Climate and Soil

As compared with early strains of cauliflower, early-sprouting broccoli is somewhat more cold and heat resistant and is not blanched. Also, both individual plants and those set on a certain date can be harvested over a longer period of time.

Culture

The cultural program is much the same as for cauliflower. In the East, spacing is usually 15–18 inches apart in rows 3–4 feet apart. In California, the plants can be spaced about 8 inches in the row when planted in double rows 13 inches apart on beds for the production of center heads only. Closer spacing than 8 inches may result, with some strains, in the failure of many stalks to meet freezing or market requirements. Furthermore, even at an 8-inch spacing many stems of the more quickly maturing strains may fail to meet the freezer's minimum of ¾ inch at a point 6 inches below the top of the bud cluster. When thinned to a 12-inch spacing the total yield is generally reduced below that of an 8-inch spacing. As a compromise with the early strains a spacing between plants of slightly more than 8 inches is likely to be more satisfactory.

The deeper the green of the heads, the better are the appearance and quality. Therefore a fertilizer high in nitrogen may have special merit.

Harvesting

The main head and side heads are cut when young and tender. Harvesting must be done before the blossom clusters begin to open. After a few yellow petals show the heads have little market value. Part of the stem is cut with the head, the length of stem depending on its tenderness, its size, and the position of the head. After the central head is removed, side heads develop more rapidly, soon attain usable size, and produce a crop for several weeks. The yield per plant is 1½–2 pounds of heads for the season. The individual heads are light in weight.

If broccoli is to be harvested in the Sacramento Valley, Calif., in the early fall, then the very early or early strains are preferable

and are seeded in July. For late fall and winter harvest, the midseason strains are best and can be seeded until early in August. September 1 is too late for direct seeding in this area.[212]

CONTAINERS

Western broccoli is shipped in the pony refrigerator crate, the usual pack being 28 bunches. In South Carolina a crate measuring 7½ × 15 × 18¾ inches, inside, is used. In New York and New Jersey 8 bunches are commonly packed in re-used, wire-bound half citrus fruit boxes (9½ × 9½ × 19⅛ inches, inside).

Insect and Disease Control

Aphids, caterpillars, and flea beetles are the chief insects, and damping-off, club-root, black rot, and blackleg the chief diseases. For control, see the Index.

BRUSSELS SPROUTS

Brussels sprouts is the Tom Thumb of the cabbage family. The sprouts, about the size of a walnut, resemble miniature cabbages and are borne in the axils of the leaves along, and around, the main stalk, progressively from the bottom upwards. The sprouts are cooked and sometimes are pickled.

History

This crop has been grown near Brussels, Belgium, whence it gets its name, since the fourteenth century. By 1793 it was an article of international commerce. "It is not difficult to imagine that the Cottager's kale may at some time have shown a tendency to form solid sprouts, and thus by selection the Brussels sprout may have been evolved. At any rate, the hard buttoning character of the Brussels sprout is only maintained by continuous selection, and in poor stocks there are always some plants with loose sprouts to be found, and such plants much resemble the Cottager's kale in character." [142]

Classification and Varieties

A. Dwarf (under 20 inches): Catskill, Dwarf Perfection, Dwarf Gem, Early Dwarf.

B. Intermediate or half dwarf (20–24 inches); includes the most widely grown varieties: Long Island, Dalkeith, Half Dwarf, Paris Market, Covent Garden.

C. Tall (over 24 inches); the taller sorts commonly give a high percentage of loose, open sprouts which are inferior for storage: Amager Market, Danish Prize.

Producing Brussels Sprouts

Soil, Manure, and Fertilizer

Brussels sprouts thrive on soils ranging from a good sandy loam to a heavy clay. A comparatively heavy soil results in harder sprouts. The plant is, like cabbage, a gross feeder and needs a highly fertile soil. It will not tolerate "wet feet."

Planting

Systems of seeding and planting are like those for cabbage. Spacing is 20–30 inches in rows 3 feet or so apart.

Removing the Terminal Bud

During late summer the terminal bud is removed with a knife. This results in quicker and better development of the lateral buds, the lower ones first, the others following, until the stem from ground to top is a compact mass of sprouts. The sooner the terminal bud is removed after the sprouts are formed the sooner they become ready for picking. This work may be done at intervals to regulate the harvest. Loose and deformed sprouts may result from nipping out too big a piece, especially when the plants are young. When heads begin to form, the lower leaves may be broken off progressively to give the sprouts more room. The top leaves are left, as they supply nourishment.

Irrigation

Brussels sprouts, like most cole crops, need a moist and cool soil environment, and in this requirement irrigation can play an important part (see Cabbage).

Cultivation

Cultivation controls weeds and so conserves moisture. Since many of the roots may grow within 2–3 inches of the soil surface and spread horizontally between the rows, cultivation should be

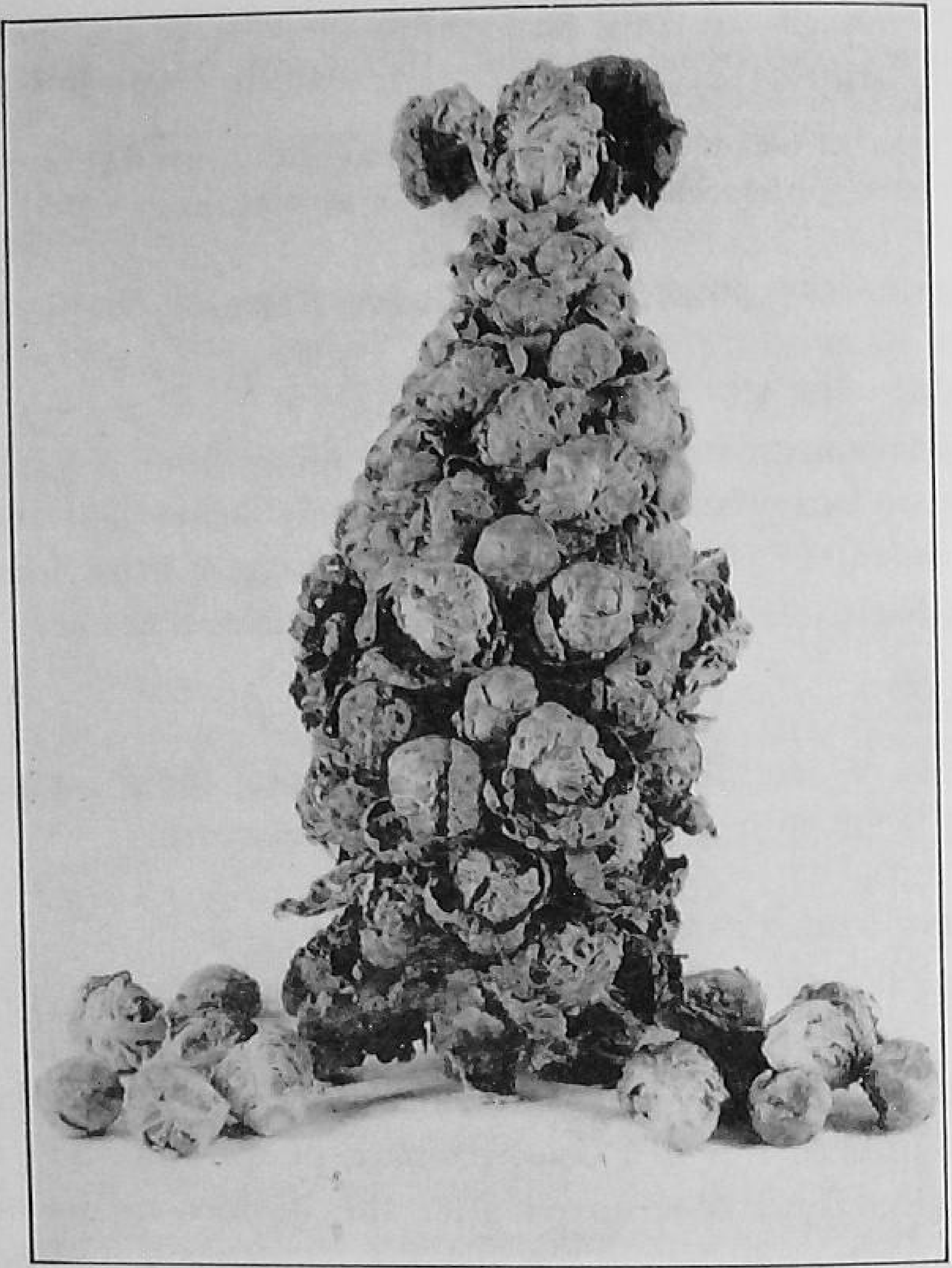

FIG. 53. Brussels sprouts. The laterally borne heads resemble miniature cabbages.

shallow. Root destruction by deep cultivation may offset any benefit from a soil mulch. If the heads begin to burst, growth may be checked somewhat by the methods suggested for cabbage.

Harvesting

When the heads develop like small, round, firm cabbages they are ready for harvest. The plants will stand considerable frost in the fall; in areas with mild winters they may remain outdoors. For high yields and quality, the plants are picked over several times, the lowest sprouts being taken each time. The upper sprouts increase in size after the lower ones are picked. If the first picking is delayed until the lower leaves begin to turn

yellow, the sprouts get tough and lose flavor. The heads become light colored if not picked at their prime.

In picking, the leaf below the sprout is broken off, and the sprout is broken from the stalk. Pressure on the sprouts is exerted downwards to avoid risk of dislodging the plant. If the whole plant is to be taken, the leaves are first clipped off with a sharp sickle or hook, care being taken not to slash the sprouts, the stalks are dug or cut off close to the ground, and the heads are removed later.

Containers

Brussels sprouts are shipped from California in 25-pound drums, or in 12-ounce transparent bags packed 24 to a wire-bound crate. In the East, the sprouts are commonly marketed in 1-quart berry boxes, packed 16 or 24 to the crate.

Storage

Brussels sprouts store well for several months under cool, moist conditions with good air circulation. The heads keep better on the stalk than off it. The plants are pulled up or cut off near the ground, before freezing weather sets in, and are stacked upright in storage.

Insect and Disease Control

Aphids, cabbage worms, flea beetles, damping-off, club-root, black rot, and blackleg are the chief insects and diseases. For control, see the Index.

CHINESE CABBAGE

Chinese cabbage when sown in the spring commonly fails to form desirable heads. This fact has led many persons to conclude that this vegetable cannot be grown successfully in their area. Seeding at the proper time, selection of suitable varieties, and adequate moisture are essential. Good crops result on muck in areas where killing fall frosts hold off until comparatively late and in regions with mild winters. Chinese cabbage is used fresh for salad or boiled as greens.

History

Chinese cabbage was mentioned in the first Chinese treatise dealing with plants, which was written by Ki Han of the Chin Dynasty, A.D. 290–307. This plant and rice are two of the chief food crops cultivated on the flood plains of China.

Classification and Varieties[219]

A. *Leaves obovate;* petiole short, broad, prominently winged, flattened or only slightly concave on adaxial surface.

1. Plant forming true heads. Leaf setose.
   - (*a*) Head long and narrow with leaf tips overlapping to form pointed apex: plant erect; leaf dark green, finely savoyed; secondary veins many, appearing parallel: Chihli, Michihli.
   - (*b*) Head medium to long with leaves curling outward at tips; plant semi-erect; leaf intermediately green, coarsely but heavily savoyed; secondary veins medium in number, palmate: Wong Bok.
   - (*c*) Head round or only slightly oblong with leaf tips overlapping; plant spreading; leaf intermediately green, moderately savoyed; secondary veins medium to few in number, palmate: Chefoo.
2. Plant not forming true heads.
   - (*a*) Leaf setose; leaf margins incised, very wavy; leaf intermediately green, moderately savoyed: Hagaromo, Market Pride.
   - (*b*) Leaf glabrous.
     - (i) Leaf margins incised, very wavy; leaf light yellowish green, coarsely but lightly savoyed: Giant Shuntang.
     - (ii) Leaf margins entire to slightly undulate; leaf light yellowish green, surfaces generally smooth, but occasionally very slightly savoyed: Santo-Sai, Chokurei.

B. *Leaf orbicular;* petiole as long as leaf blade, not prominently winged, deeply and narrowly concave on adaxial surface; plant not forming true heads, erect; leaves not overlapping, dark green, glabrous, thickly covered with bloom not savoyed; leaf margins entire, very slightly waxed: New Joy.

Chihli forms long, slender (15–18 $\times$ 4–6 inches) heads. *Michihli,* an American variety introduced by Ferry-Morse Seed Co. in 1948, is slightly more vigorous than Chihli and shows a more attractive, richer dark-green color of the outer leaves, without the yellowish cast. The trimmed heads are attractive, well blanched, hard, and firm.

Producing Chinese Cabbage

Chinese cabbage plants quickly bolt under conditions of long days, high temperatures, and low soil moisture. The best plan is to seed about 1 inch deep where the plants are to mature. Time of seeding is very important; see Table 3.

FIG. 54. Chinese cabbage, Chihli variety.

The rows are spaced 1½–3 feet apart, depending on area involved, method of cultivation, variety, and various other factors. When the plants are 3–4 inches high, they are thinned in the row to 12–14 inches for narrow, upright varieties and to 20–24 inches for wider types.

Head types are harvested much like cabbage. Nonheading types are harvested when the leaves reach edible size.

TABLE 3

MEAN PERCENTAGES OF PLANTS FORMING HEADS OF CHIHLI AND WONG BOK AT DIFFERENT DATES IN WYOMING [219]

Date of Sowing	Plants Forming Heads: Wong Bok, %	Plants Forming Heads: Chihli, %
May 1	0.00	8.54
May 15	15.98	19.35
June 1	22.80	91.84
June 15	34.32	92.28
July 1	27.18	86.59
August 1 *	0.00	0.00

* Plants killed by frost before sufficient time had elapsed for head formation.

KOHLRABI

Kohlrabi (which is the German name for cabbage-turnip) resembles an aboveground turnip, the fleshy edible portion being an enlargement of the stem. It does not keep well, but it provides a fine frozen vegetable. For good quality, the growth should be rapid and without check. The small heads may be boiled in salted water, drained, cut in quarters when cold, and

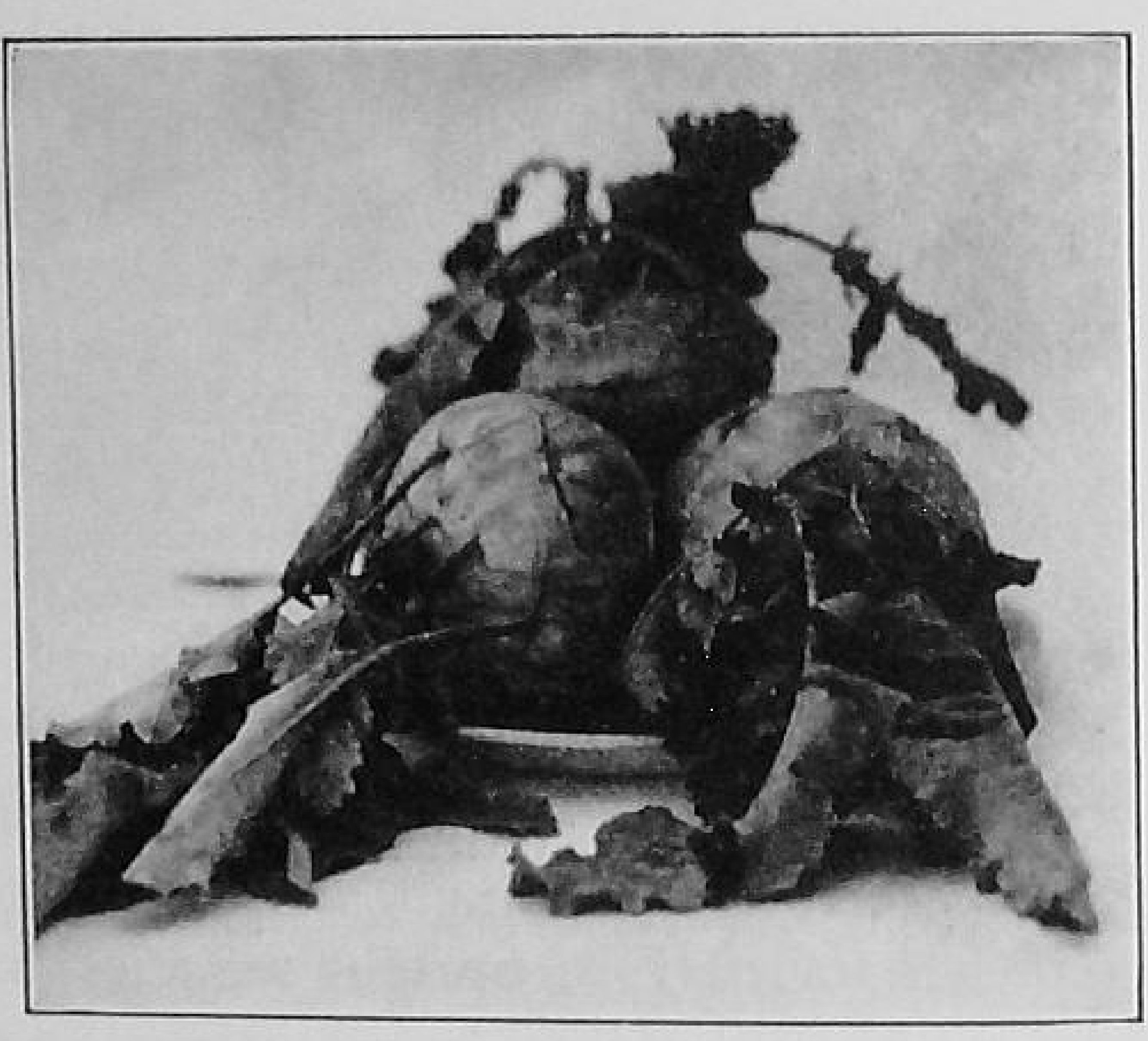

FIG. 55. Kohlrabi.

dressed with oil and vinegar. It may be served as a salad.

Kohlrabi originated in the coastal countries of northern Europe. It likely developed from marrow-stem kale, a cattle type of kale with a thick stem and few if any shoots.

The heads of *White Vienna* are globular and light green. *Purple Vienna* is about a week later; the head is purplish, and the flesh is greenish white.

The plants are started under glass for an early crop. For a later crop, seed is sown in rows 1½–2½ feet apart where the crop is to mature, in about 2 months. The plants are thinned to 6–8 inches apart in the row. Transplants are set 6–8 inches apart in the rows. Considerable manure may be applied. Harvesting is done when the thickened stem is 2–3 inches in diameter. It becomes woody with age.

10 · POTATO

The world's potato crop of about 7 billion bushels per year equals and probably exceeds that of wheat. Because of their bulk in proportion to value, potatoes are more important in domestic than in international trade. The ease of storage adds to their usefulness. The potato is one of the cheapest foods that can be obtained. It is a food of which few persons tire, being in this respect much like bread.

Potatoes do best in a comparatively cool, moist climate and on the lighter soils. Annual production in the United States is about 400 million bushels. Maine, New York, Michigan, Ohio, Wisconsin, Minnesota, Idaho, Colorado, and Virginia are the main commercial areas. The South produces a winter crop. In Canada, the five eastern provinces produce over 75 percent of the total crop, with Ontario, Quebec, and Prince Edward Island the leaders. Besides those raised for market, potatoes are very widely grown in home gardens up to and within the Arctic Circle.

During World War II the British Medical Association expressed the view (*Toronto Star Weekly*, Nov. 8, 1941) that, if Britain were limited to two foods, the best choice would be potatoes and milk. Few crops have a higher yield per acre than potatoes. A fair average is about 200 bushels per acre, but some growers average several times this amount. Yields of over 1,100 bushels per measured acre have been reported in official tests in Colorado, California, British Columbia, and Ontario.

History

There are two general areas in South America where potatoes first appeared. On the south Chile mainland and Chiloe Island, under conditions of rich soil, abundant moisture, low altitude, and long days, the natives improved *Solanum tuberosum*. On the high Andean plateaus of Colombia, Peru, Ecuador, and

Bolivia, with their cold arid climate, altitudes of 8,000–12,000 feet, and short days, *S. andigenum* was developed. The former species has become our cultivated potato. When the Spaniards reached South America, they found that the potato was the main food plant of the inhabitants of these plateaus.

The first-recorded contact of the white man with the potato was made in 1537 when the expedition of Gonzalo Jiminez De Quesada made the chief if least acclaimed discovery of the Spanish Conquest. In Sorocota Village, about latitude 7°N., the Spaniards found the potato under cultivation.

The potato was looked on with distrust when it was first introduced into Europe; for nearly a century many refused to eat it because they feared it was poisonous. This idea resulted from the finding that the plant contains solanin, a poisonous compound that is found in the green parts of the plant; it is found in tubers exposed to light, and it accumulates in the region of the buds about the time sprouting takes place and may become abnormally high if germination is withheld.

The potato was grown as a field crop in Ireland before 1663. Legends crediting Drake and Raleigh with its introduction to England from Virginia lack definite foundation. There is no record that any plants growing in Virginia at that time (1586) closely resembled the potato growing in South America. Possibly Raleigh's men secured potatoes from a Spanish ship carrying them to Spain. In 1663 the Royal Society of England tried to encourage potato growing to provide a cheap food in case of famine; a famine in Scotland in 1743 brought the crop into prominence.

The Caribbean word [for sweetpotato] is, of course, *batata,* and this has been taken into Spanish and Portuguese. For some unknown reason the Latin specific epithet for this plant makes use of the plural form *batatas.* This word has suffered corruption eventually into the English word "potato," having become transferred by some quirk of fate to the Andean plant, whilst the *Ipomoea* potato has been relegated to second place and distinguished by the qualifying word "sweet." Strangely enough, even the original word *batata* in Portuguese now refers to *Solanum tuberosum,* whilst the sweet potato is named "batata doce." In Spanish, however, *batata* is equivalent to "sweet potato," the Spanish word for the ordinary potato being *patata* or *papa.*[167]

Improvement in North America

In the United States, potatoes were grown at Londonderry, N. H., in 1719, from stock brought from Ireland. In the next 140 years, few good varieties appeared. But from 1860 to 1900 great progress was made. Prominent among the early breeders were D. E. Goodrich, Utica, N. Y., and C. G. Pringle, Charlotte, Vt. The ancestry of about 170 varieties can be traced to Goodrich's Garnet Chili, a seedling of Rough Purple Chili.

The potato breeding program of the U. S. Department of Agriculture began in 1910. In 1929 it was reorganized as the National Potato Breeding Program, cooperating with a number of state experiment stations, some of which had potato breeding programs of their own. The program is now organized in every potato growing section of the United States.

Plant Characteristics

The potato is an annual, herbaceous dicotyledon but may be considered as a potential perennial because it reproduces itself vegetatively by tubers. At the end of the growing season the plant food developed by the leaves has been largely transferred to the tuber or perennial part of the plant. This habit resembles that of asparagus, rhubarb, and other plants that retain their living parts from year to year below ground.

The new sprout depends almost entirely upon the seed-piece until the first leaves can manufacture more food than they can use. This means that potato plants generally draw upon the old seed-piece until the plants are 8–12 inches tall.

Roots

Roots originate from the stem in groups of 3, 5, or 7 in crescent-like arrangement at each node directly above the lateral stem buds. The roots usually grow laterally for 10–18 inches; then they grow downward. Most of the roots are in the top foot of the soil and relatively few grow 3 feet or more deep.

Flower Color

Flower color is often helpful in checking trueness to variety at the time of bloom. The flowers are white in Early Ohio, Russet Burbank, Green Mountain, Teton, Chenango, and

Houma. They are white with pink tips in Mohawk, lilac in Sequoia, lilac with white tips in Irish Cobbler and Chippewa, pink in Triumph, light lilac in Katahdin, light lavender in Kasota, lavender in Warba, reddish purple in Sebago and Pontiac, and bluish violet with white tips in Rural, Russet Rural, and Pawnee.

Fruit and Seed

The fruit of the potato is a 2-celled, brown or purplish-green, many-seeded berry. It is about ½ inch in diameter, globular or oval, and has 200–300 small seeds embedded in the pulp. New

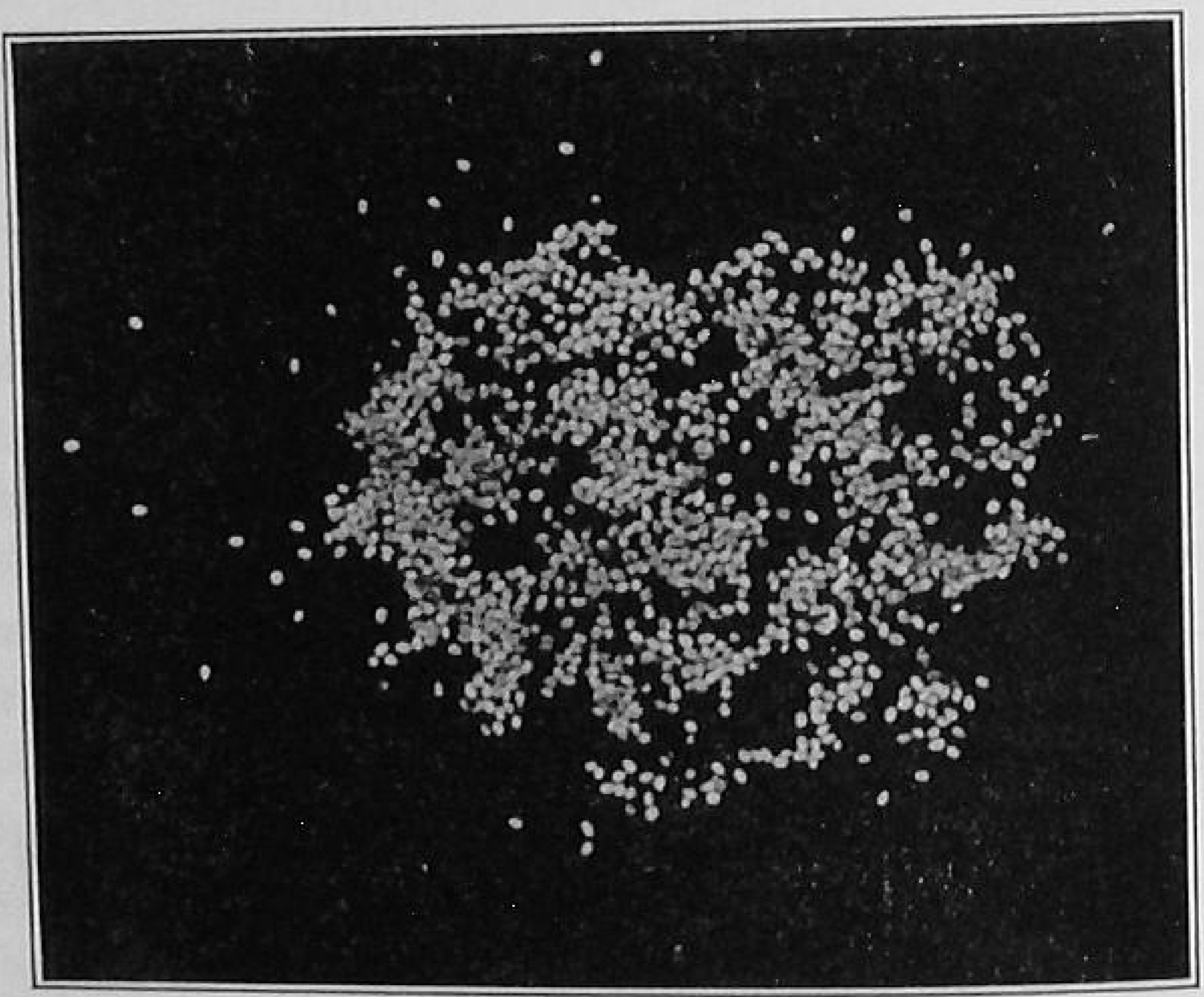

Fig. 56. True seed of potato.

varieties can only be developed by growing the plants from true seed or from bud variation. Seed production is subject to several factors, e.g., the variety and the length of the light period. At Edmonton, Alberta, Katahdin sets seed freely, whereas Netted Gem produces little. At Beltsville, Md., 16 hours of daylight are best for flowering and fruiting. With Triumph, a maximum set of fruit is obtained with a 24-hour photoperiod during 11–70 days after planting. Seeds kept in the dark at 32°F. may remain good for many years.

Flowers occur and fruit may develop from them when days are long and cool. Tubers will develop when there is accumula-

tion of surplus carbohydrates in the plants, whether or not flowers are produced. In northern or high-altitude regions where potatoes bloom and set seed-balls profusely, yields of tubers are reduced in proportion to the weight of the seed-balls. Therefore, growers in those regions should avoid varieties capable of producing large crops of seed-balls.

Tuber Development and Anatomy

A potato tuber is a modified storage stem with its axis greatly shortened and its lateral members very weakly developed, the latter being "eyes." Tubers begin to form when the plants are 5–6 inches tall and are completed by the time the flower buds are formed. Conditions during this period determine the number of tubers set.

Stolons (small stems) grow out from the main stem a short distance above the old seed-piece. In some varieties the stolons are short, so that the tubers are clustered closely around the old seed-piece. In other varieties the stolons are much elongated or may continue through and beyond the first tubers, giving the potatoes the appearance of being strung on a thread. But these stolons never grow a root, nor do roots grow from tubers.

From the outside, the chief zones in the mature tuber are periderm, cortex, vascular ring, perimedullary zone, and pith. The periderm is the protective outer covering, about 6–10 cell layers thick and broken only by lenticels (prominent spots). Its impermeability to water, air, and destructive microorganisms determines the keeping quality of the tuber. The cortex is a narrow band of storage tissue within the periderm. The narrow vascular ring, inside the cortex, is composed of secondary xylem and phloem, outside of which the primary phloem forms a relatively limited storage region. Most of the tissue of the mature tuber is in the perimedullary zone. This region is mainly storage parenchyma, containing many groups of inner phloem. Sugar (from the leaves) moves through the phloem into the nearby enlarging cells where it is stored as starch. The pith forms a small central core from which radiate arms of medullary parenchyma, so that the region appears irregularly star shaped in transection. Its cells are lower in starch, have a higher percentage of water, and are more colorless than adjoining tissues.

Most plants have only external phloem, i.e., phloem outside the ring of xylem or water-conveying vessels. Phloem refers to the long slender cells that convey food from the leaves through stems and stolons into the tubers. In the potato stem there are also food-carrying tubes inside the ring of xylem. If pests or hail destroy tissues located as deeply as the external phloem in the stem, the food can still move to the tubers through the internal phloem. If the stem is damaged so that the internal phloem is blocked, tubers may develop from buds located above these injured places.

Tuber Formation

Physiology. When temperature is high and days are long, the material manufactured by the leaves is used in the normal living process of respiration and for new growth. When the carbohydrates are not used as rapidly as manufactured, they accumulate in the leaves as surplus material, to be moved in the soluble form of sugar down through the stems and out through the stolons to terminal or lateral buds. Here sugar changes to starch and cells divide and enlarge, converting the stolon buds into tubers. Tuber development does not retard top growth as does the formation of flowers or fruits, because tubers grow only when the material going into them cannot be used by the plant for other purposes.[416, 417]

Environment. When days are hot (75°F. or higher) and long (15 hours of light or more), large vines and many long or branched stolons are produced but tubers develop very slowly or not at all. When days become cooler and shorter, top growth and respiration diminish. Then, because of the accumulation of surplus carbohydrates, tubers grow with increasing rapidity until the plants are killed or die of old age. The grower need not become alarmed if late-crop vines seem excessively large while the tubers are still very small. During the cool, shorter days which follow, provided soil moisture is ample, the vines can produce a large crop in a short time.

With the early crop, especially in the South, the cool short days in the early life of the plant are less favorable for vegetative growth than for tuber formation. Therefore, tubers are formed comparatively early on relatively short and simple stolons, and grow for a long time.

With any combination of day length and temperature, tuber formation is hastened by factors that retard vegetative growth, e.g., a shortage of nitrogen or water. When early tuberization is induced by such means, the tuber crop will be small unless conditions improve later to increase the leaf area. Leaves kept healthy as long as possible offer a large area for manufacturing carbohydrates which accumulate in tubers when conditions become favorable.

Early and late types differ greatly in their ability to continue vegetative growth when grown as a late crop.[418, 419] The early types stop growing and tubers develop much earlier than in the late types. In all types grown as an early crop, provided days are short and cool during the early life of the plants, there is little difference in the duration and extent of vegetative growth. The vines are relatively small, and the tubers are developed early and at about the same time, particularly with potatoes in the South during winter and spring. Consequently, varietal differences that involve time of tuber development or size of vines are much more apparent with the late crop as grown in the North than they are with the early crop or in the South. Likewise, varietal differences are greater on rich or heavy soils or on irrigated areas than on low-fertility, light, or dry soils.

If the long summer days are very hot, respiration may use up the carbohydrates so that little or none are available and plant growth stops. If very adverse conditions occur after tubers are partly developed, the plants may withdraw water from the new tubers, causing them to become soft and spongy. Some "food" may also be withdrawn, thus reducing the dry matter content or food value of the tubers. This happens when early potatoes are left unharvested in hot soil while the vines are dying. The vines are not manufacturing carbohydrates but are withdrawing them from the new tubers and dissipating them by respiration. Because of this loss and in order to obtain maximum yield and quality, early potatoes should be harvested after the vines have attained their maximum size but before most of the leaves have died.

During tuber development, low temperatures affect tubers in various ways. Tubers are shorter, wider, and flatter than at high temperatures. In colored varieties, the skin is darker. More starch is present, the total percentage of dry matter is greater,

and when cooked the potatoes are more mealy and have better flavor.

The Potato Eye

The potato eye is a leaf scar with its subtended axil, which contains a suppressed lateral bud and undeveloped internodes. The eyes show a spiral arrangement. A string passed around the tuber and held in position with a pin in each eye demonstrates

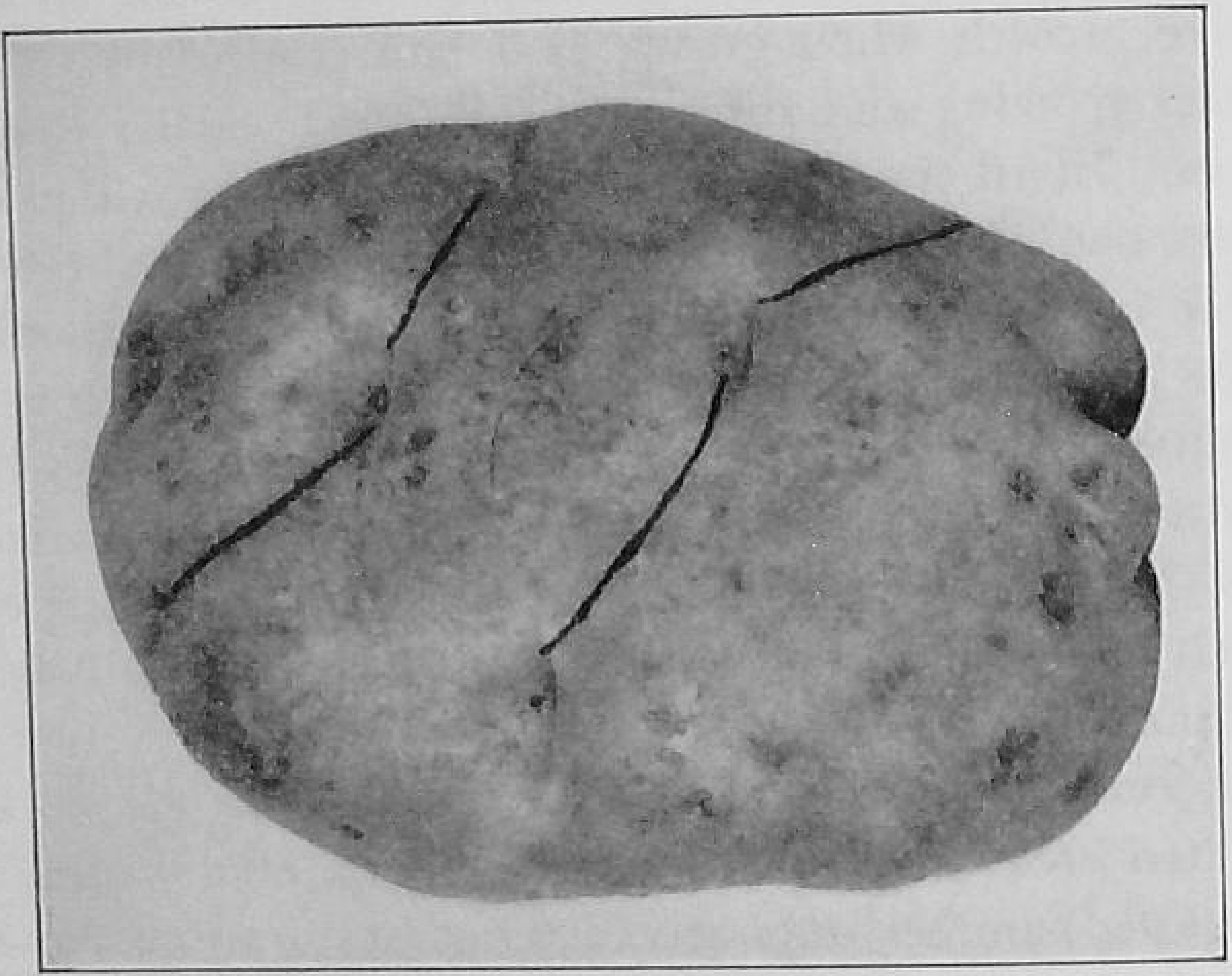

Fig. 57. Spiral arrangement of potato eyes.

it. Each eye contains at least 3 buds arranged in the form of an obtuse triangle and protected by more or less conspicuous scales. Often, however, a large number of buds are present forming a secondary spiral.

The lowest basal eye in a tuber is small and inconspicuous. After the first or second turn of the spiral the eyes become characteristic of the variety. The apical eye cluster is commonly not in direct line with the main axis but eccentric; the eyes composing it are small and contain fewer buds than those of the body of the tuber.

As the tuber enlarges, new buds are constantly differentiated from the growing apex, and the older ones gradually develop to maturity. In this growth and differentiation, the scales, once prominent, lag in development and finally atrophy, leaving a scar, the *brow* of the mature eye.

Varieties

Warba and *Red Warba* are very early; the tubers are commonly rough. *Irish Cobbler* is a leading early variety; the tubers are blocky and roundish, deep eyed, creamy white, and comparatively high in starch. *Waseca* (red), *Chisago* (white), and *Satapa* (red) were introduced in Minnesota in 1947.

Triumph is early to medium and much grown in the Middle West and to some extent in California. The potatoes shipped northward from Louisiana, Texas, and Florida are often of this variety. *Progress* tubers may crack less than Triumph in harvesting. *Early Ohio* (long, pink tubers) is grown in the Red River Valley of Minnesota and North Dakota. *Pawnee* is medium to early; the tubers are short-elliptical to roundish, cream to dark-cream buff. *Kasota,* a light-red type, is highly resistant to fusarium wilt in the Middle West. *Yampa,* a scab-resistant type, was introduced in Colorado in 1947.

White Rose is a leader in California. *Calrose* is moderately resistant to late blight and high yielding under irrigation in California.

Green Mountain is medium late; the tubers are oblong-flattened with blunt ends, the skin dull creamy white. It excels in the quality of its dry mealy tubers, but is susceptible to most potato diseases and especially to net necrosis. *Mohawk* is excellent for baking. *Canus* has done well in some parts of Canada.

Rural New Yorker (Smooth Rural), formerly a leading late variety, is too subject to diseases. *Russet Rural,* also late, does not bruise or "skin" as easily as smooth types and is comparatively free from scab.

Russet Burbank (Netted Gem, Idaho Baker) tubers are large and cylindrical with blunt ends and shallow eyes, late, resistant to scab, high in starch, and keep well. The skin lacks the brown pigment of most russet types.

Perfect Peachblow (Red McClure) does best on light soils at high altitudes as in Colorado. The tubers are dark red, spherical with few, shallow eyes. It is high in starch.

Chippewa tubers are creamy white to dark-cream buff, smooth, and oval to oblong, with few, shallow eyes. It is only fair for cooking and storage but is free from net necrosis.

Katahdin tubers are attractive, short-elliptical to round, and medium thick, with a cream-buff skin, late. Comparatively deep planting helps avoid sunburning. It has become the leader in North America.

Sebago is later than Katahdin. The tubers are ivory yellow, smooth, and nearly round, with few and shallow eyes, resistant to rots initiated by the late-blight fungus, and fairly resistant to scab. The tubers tend to cling to the vines when dug. *Russet Sebago* is a sport of Sebago.

Kennebec combines high midseason yield and good cooking and storage qualities with a high degree of resistance to late blight, mild mosaic, and net necrosis. The plant resembles Green Mountain. It produces smooth, shallow-eyed, white tubers that are shaped like Katahdin.

Pontiac (and its mutant Dakota Chief, or Red Pontiac) is high yielding, late, and red. *Potomac* possesses good baking quality, and has moderate resistance to late blight and to injury by flea beetles and leafhoppers. *Ontario* is late and highly resistant to scab. *Erie* is more resistant to ring rot than Katahdin or Green Mountain but not as resistant as *Teton.*

De Sota (red), *La Soda* (red), and *La Salle* (white) were bred for adaptability to the short days of the South and to produce satisfactorily in northern seed-producing areas. *Pungo,* because of its high yield and blight resistance, may be suitable for the fall or spring crop in areas like Virginia. *Keswick,* a 1951 introduction through the National Potato Breeding Project, possesses a high degree of late-blight resistance and yields well in early and midseason crops. The tubers are elliptical to oblong.

Climate and Soil

In general, relatively cool conditions (60–75°F.) are most favorable for plant and tuber development. Potato culture is most successful in northern areas, but good crops of early varieties are grown in the South in the spring and fall.

In the hot weather of midsummer, plants may produce heavy vines but set few tubers. The optimum for tuber yield is about 63°F. At 85°F. no tubers form. The reduction in the carbohydrates available for translocation that results from increased respiration at the higher temperatures roughly corresponds to

the reduction in tuber growth. Thus, the rate of tuber growth is a function of the available carbohydrates. Deficiency of carbohydrates arising from excessive respiration is a limiting factor in plant growth at temperatures above the optimum.

In certain districts in California,[98] high yields may be obtained where the summer daytime temperatures frequently exceed 100°F. The soil temperature is kept relatively low either by frequent irrigation on the sand and silt types or by the continuous subirrigation practiced in the peat districts where the water level is held 18–24 inches from the soil surface until the crop approaches maturity.

Potatoes, though heavy feeders, leave the soil in good condition for the next crop. They should be produced in a rotation, for otherwise certain disease organisms may accumulate in the soil. They should not be planted on a site infested with wireworms during the previous year or so. Wireworms bore into the tubers and thus ruin the crop as table stock. There should be enough time between crops to overcome temporary nutrient and moisture deficiencies.

The early crop is usually grown on light soils, which warm up first in spring. Sandy soil permits a free development of the root system, but is often deficient in humus and "plant food" and dries out quickly. Most of the late crop is grown on soils ranging from a sandy loam to a silt or clay loam. These soils, if liberally supplied with humus, hold plenty of moisture and are cool. Muck or peat soil will give high yields of potatoes if it is well supplied with potash and phosphorus.

Soil Reaction

In general the more acid the soil the less scab, but at low or high *p*H values the yield may suffer. A *p*H of 4.8–5.6 is usually good from yield and scab standpoints. When scab is not a factor a somewhat higher *p*H is satisfactory.

On some mucks, 1 ton of sulfur may cause a drop from *p*H 6.0 to *p*H 5.0. Also, on some mucks it is necessary to apply 10 tons of limestone to raise the reaction to *p*H 5.0. It is not wise to plant potatoes immediately after applying limestone, as direct contact of the tubers with limestone may increase scab.

Soil Preparation

The soil should be plowed deeply, preferably 8–10 inches, but it is not wise to turn up more than ½ inch of subsoil. The depth of the furrow may need to be increased from year to year until a proper depth is reached. Fall plowing is preferable for the early crop, except where the soil may blow or pack badly in winter. Except in regions of light snowfall where clods are not broken up by freezing and thawing during winter, the land should be left rough to catch and hold as much snow as possible. If the soil is heavy and tends to be wet, it may be plowed in narrow strips with open furrows between them to facilitate drainage and to allow early planting. For late potatoes, the land should be plowed in early spring and then harrowed until planting time to prevent weed growth.

Manure and Fertilizer

Enough nitrogen, phosphoric acid, and potash to produce 400 bushels of potatoes per acre is provided by 20–25 tons of manure so handled as to avoid leaching before being spread. But growers seldom have access to the required amount. Therefore, fertilizers are resorted to, entirely, separately, or as a supplement to manure or crops plowed under, or in a rotation. More fertilizer will be taken up by larger crops and more perhaps leached in wet seasons than in dry ones.

Fertilizers high in potash are used to good advantage in most potato areas. Chemical nitrogen, which is quickly available, is used in widespread areas for early potatoes. On many soils, potatoes respond to application of phosphorus.

The time in the development of the potato plant when it uses the various fertilizer elements is important in the choice of fertilizer. Potato plants capable of yielding 400 bushels per acre absorb about 120–160 pounds of nitrogen, 25–30 pounds of phosphoric acid, 200–250 pounds of potash, 60 pounds of calcium oxide, 30 pounds of magnesium oxide, and about 10–12 pounds of sulfur in producing this yield (*Maine Bulletin* 411-C). Green Mountain absorbs about 70 percent of its total consumption of nutrient elements 50–80 days after planting. Early varieties, e.g., Cobbler, make more rapid growth early in the

season than later varieties, and their period of more rapid absorption of nutrients also occurs earlier.

These changes have taken place in some northern Wisconsin potato soils since they have been under cultivation: [31] soil acidity has increased from medium (*p*H 5.5) to strong acidity (*p*H 4.5); the available phosphorus content is three to five times that of the virgin soils; available potassium has decreased about 50 percent. This shift in nutrients has been brought about largely by an unbalance in the fertilizer used. Tests showed that yields can be greatly increased by applying 1,200 pounds per acre of 6-6-18 fertilizer broadcast plus 800 pounds of 3-12-12 at the side of the seed in the row. Owing to the increase in acidity, these soils are now deficient in available magnesium but have an excess of soluble manganese. Both of these conditions can be rectified by small applications of finely ground dolomitic limestone. Adding soluble magnesium in the fertilizer is also advised.

Along the Atlantic seaboard, potato foliage sometimes fails to develop the normal green color, at first being pale green and later changing to light yellow owing to magnesium deficiency. The loss of green starts at the tips and margins of the first leaves and progresses inward between the veins toward the centers of the leaflets. The leaves display a definite bulging between the veins and a thickening and brittleness. The main factors causing the magnesium deficiency are heavy use of acid-forming fertilizers low in magnesium on soils already too acid, the leaching effect of prolonged rainfall before planting, and the lack of soil organic matter.[233] Remedies include adding available magnesium to the fertilizer, using potassium magnesium sulfate as a source of potash, and applying dolomitic limestone.

Fertilizers may influence the composition of potatoes, especially when grown on soils where deficiencies in nutrient elements exist.[109] In many cases phosphate fertilizers increase the phosphorus content and potash the potassium content of the tubers.

Placement of Fertilizer

The fertilizer is well placed if it is distributed in narrow bands about 2 inches to the side of the seed and slightly below its level. Modern planting machinery is designed to place the fertilizer suitably. But if large discs throw a ridge over the

seed, the fertilizer is picked up and moved above the seed-piece. Planting so that a furrow is left with a small amount of soil over the seed avoids the difficulty. The broadcast method is good when large amounts of fertilizer are used or when only a maintenance application is needed. The plow-sole method gives good results, particularly on the heavier soils.

The seed or young plant is often injured if the fertilizer is applied with the seed. Contact with fertilizer is more injurious to freshly cut seed in a dry soil than in moist soil, and the soluble constituents are the most injurious.

"Seed"

The potato is propagated from tubers which are commonly spoken of as seed. But true seed develops from flowers, in seed-balls aboveground.

Maximum crops are not obtained unless the seed is of the best, viz., free from disease, of a suitable variety, free from mixtures, grown under favorable climatic conditions, and firm and sound with sprouts just beginning to show when planted. Simply selecting smooth, nice-looking tubers from a bin may hasten the degeneration of seed stock. Plants affected with leafroll or mosaic produce tubers that look good in the bin but are not fit to use as seed. Some of the tubers in the same bin that are knobby and of poor appearance may be better seed than the others, because it takes a vigorous plant to produce knobby tubers. A much too common practice is planting tubers that are left after the marketable ones have been sold; many tubers are culls as a direct result of being diseased.

Disease-free seed means particularly that the potatoes are free from, or have a very low percentage of, certain virus or "running-out" diseases, and is often more important than variety in the securing of good yields. To be certified, seed must meet certain requirements (see Potato Diseases).

Sprouting Habit

There are at least 3 buds to an eye, and commonly about 15 eyes and therefore at least 45 buds per tuber. A very small proportion of the buds normally sprout when a tuber is planted. Tubers after maturity have a 2- to 3-month rest period during

which time they will not sprout. For a time after the end of the rest period the tubers are apically dominant. At this stage only 1 bud, usually the terminal bud, develops. By planting time, apical-bud dominance is weaker, and 2 or more sprouts usually develop from each seed-piece. Later, more sprouts arise. Potatoes produce more sprouts the following spring when they mature early rather than late in the fall, at 39°F. rather than at 32°F., when wilted, and when the seed-pieces are large.

Growers of early varieties in much of the United States long ago learned that northern seed would outyield seed produced locally. Seed potatoes are planted later in the North, and so are in a less advanced sprout stage then southern stock. They set fewer tubers, but they are of better size.

Tubers for the early crop should show the beginnings of sprouts when they are planted, as this means quicker germination and growth. It gives the plants a better chance to outgrow the rhizoctonia organism that often destroys slow-growing sprouts. It also enables early establishment of large plants that can produce much of the tuber crop before hot weather. With prompt, rapid growth the sprouts and young plants can absorb the maximum amount of food from the seed-pieces before they rot. To induce sprouting, tubers are removed from storage and held at about 65°F. for 10 days or so. Sprouts should not be longer than ¼ inch, as longer sprouts may break off when the tubers are cut and planted.

If sprouts develop too early, it is better to break them off once or twice rather than permit excessive growth of a few sprouts per tuber. The removal of a crop or two of sprouts only 1–2 inches long results in less loss of tuber substance than if the original sprouts grow longer.[420] After each crop of sprouts is removed, sprouts tend to appear from more eyes on each tuber and from more buds in each of these eyes. This may or may not be desirable according to the purpose of the crop and the conditions under which it is being produced.

For the late crop it is best to use seed-pieces from tubers held under good storage conditions for a few months after the rest period is over. Such seed-pieces usually produce 2–4 sprouts, a condition desirable for the late crop. This crop tends to set a small number of tubers that may become too large.

GREENING

Greening, i.e., spreading the tubers on the floor of a room in subdued light, results in short stubby sprouts. The sprouts become green, ¼–½ inch long, thick, tough, and hard to break off. Good seed when greened usually develops only 1 main sprout per bud-eye cluster unless the tuber is injured. To avoid shriveling, the tubers can be sprinkled occasionally, but they should not lie in pools of water. When the temperature is warm enough, the tubers may be placed outdoors in partial shade. Boards laid on the ground will prevent the tubers from touching soil and developing roots. In early-potato areas, much of the advantage of early plant emergence may be lost through killing frosts several weeks after planting.

The foregoing discussion is on seed tubers. Greening of potatoes by light causes losses when preparing tubers for cooking or dehydrating. Greening may occur in the field, in storage, and in the market. It is correlated with a development of solanin, a poisonous alkaloid. Tubers green faster [135] at room temperature than in a cooler place. Greening, as seen through the skin, fades faster in the dark at 75°F. than at 35°F., fades somewhat in a month of dark storage after 2–4 days of exposure to light, and is obscured or replaced by red or brown when it fades in dark storage. Cortical greening develops faster and fades less in Katahdin than in Chippewa and Green Mountain. Tubers exposed to light for 2 days may need over a month in warm storage for fading of the green and if exposed to light for longer periods may need several months of warm, dark storage for fading of the green.

Cutting Seed

The seed-pieces should be thick and cubical. Blocky pieces produce sturdier sprouts than thin pieces; ensure more accuracy in planting, especially with the picker-type planter; and are less likely to rot, because of the relatively smaller amount of cut surface and because they develop wound cork more quickly over the entire cut surface. This preservation of the old seed-piece is important as the sprout depends on it and the young plant until 8–12 inches tall "feeds" on it.

Most seed potatoes are cut by hand. No mechanical seed-potato cutter yet devised is able to distinguish between weak eyes, strong eyes, and no eyes at all, but a cutter may be used where the tubers have been graded to a uniform size.

To facilitate cutting of tubers a low table with a lath tacked around the edge is useful. The workmen sit at the table and use thin, sharp knives. A crate is placed beside each cutter; when a number of tubers are cut they are pulled into the crate through an opening in the lath. A cutting box can be built with a hopper that feeds the tubers to the operator. A thin knife, sharpened on both sides, is placed into a 2″ × 2″. A crate is placed under the knife to catch the cut pieces.

Each seed-piece must have at least 1 eye. The eye should be centrally situated. If the terminal eye is located at the extreme edge of the piece its sprout fails to obtain adequate nutriment and weak, weed-like secondary buds start. While tubers are dormant, sprouting is hastened by cutting close to an eye. If the eyes are too far apart for pieces of the desired shape and size, cuts may be made directly through an eye.

Size of Seed-Piece

Other things being equal, the larger the set planted the larger the crop. The amount of plant food stored, i.e., size of seed-piece, rather than number of eyes is the main factor. Large, whole potatoes usually give the largest crop, but, as it is the largest crop of marketable potatoes at a minimum cost that is desired, it seldom pays to plant large whole potatoes. Seed potatoes often cost twice as much as the price received for the resulting crop.

For the early crop, it is usually a waste of seed to plant a piece much larger than 1–1½ ounces. Pieces that weigh less than ½ ounce are too small to produce sturdy plants. Under ideal conditions a ¾-ounce piece produces a strong plant, but, if planted more than 4 inches deep or in soil that packs, the sprout may fail to reach the surface.

For the early crop, seed-pieces cut blocky to average 1–1½ ounces and with 1 or more eyes are most economical. Small tubers of this weight from clean stock should be planted whole, or, if cut, should be split lengthwise to divide the eyes of the

bud end. Tubers weighing 2–3 ounces should be split; 3–4½ ounce tubers should have the stem end cut off and then be split to bud end; 5-ounce tubers may be split from end to end and then through the middle. For late planting, 2-ounce pieces are advised.

FIG. 58. Sprouts from potato seed-pieces of different sizes. (*After Bushnell.*[52])

For types with shallow eyes and few eyes on the stem end, e.g., Chippewa, obtaining seed selected for its size, 3–4 ounces preferred, and cutting the tuber only once, through the apical or bud end, may be best. Katahdin sets fewer tubers per plant, and so each piece should have 2 or more eyes or the spacing in the row should be closer.

Growers on muck changing over from older varieties to the newer ones such as Katahdin, Chippewa, Sebago, and Sequoia have often observed more weak or missing hills, generally the result of planting seed-pieces from the stem end of the tuber which may have only 1 weak eye or even no eyes at all. Reduction in stand may result from planting pieces cut for size but disregarding the eyes, or from using stem-end pieces with weak eyes or no eyes at all.

The more plants per hill the larger is the number of tubers per hill and the smaller is their average size. Increasing the weight of seed-piece increases the number of plants, but it increases the number of tubers and reduces their average size. Close spacing also accentuates the competition between plants and reduces the size of tubers. Pieces heavier than 2 ounces or spacing in the row closer than 9 inches gives higher total yields than usual but more small tubers.

Handling Cut Seed

Seed can be cut some time before planting if the cut surfaces heal quickly. This enables work to be performed on rainy days and during slack periods, so that when suitable conditions arrive planting can proceed. Healed seed will endure exposure better than freshly cut seed.

Suberization of Seed-Pieces

Omitting practices that would bring about healing (suberization, or corking over) may result in much rot of seed-pieces in the field and a poor stand. Improperly healed pieces that are not completely rotted before the eyes can send out shoots may give rise to weak plants or to apparently normal ones. Later such plants may turn yellow and die prematurely. If still alive at digging time, they show the remnants of rotted seed-pieces clinging to the underground stems and the interior of the stems is hollow and discolored.

Three conditions are essential for suberization, viz., air (oxygen), proper humidity, and 60–70°F. Under these conditions a protective layer of cork cells will develop over the exposed cut surface. This layer forms an effective barrier against decay organisms. If any one of these conditions is lacking, cork cells will not develop and the exposed cells will die. Shriveling of the seed-piece may result, or the surface may become dry and hard and later crack. Seed-pieces may be planted immediately after being cut if the soil is not too wet or too dry and the weather is not too cold. Under such favorable conditions the pieces will suberize in the soil before the decay organisms can invade their tissues.

It may be necessary to modify slightly the method of suberization in different areas because of the variation in air humidity. The freshly cut pieces may be placed in clean, moistened burlap bags. Ordinarily the humidity within the bags is then high enough to ensure proper suberization if the pieces are kept protected in a building. If the bags of pieces are stored where they dry out quickly, they may need to be sprinkled occasionally or to be covered with more moist bags. If the weather is cold, it may be necessary to heat the building to 60–70°F. The bags of pieces should not be stacked too high, as this may exclude

air. Under ideal conditions a protective layer of cork will develop within 48 hours.

The best cork formation is obtained by using sound tubers that have been kept under ideal storage conditions. Tubers that are beginning to shrivel and those from which the sprouts have been removed at various times do not suberize readily.

Good procedures for healing seed are: (*a*) Air and disinfect the storage containers (e.g., with 1 pound of copper sulfate to 10 gallons of water) to avoid mold and rot. (*b*) Cut blocky pieces (less surface to be healed); use a sharp knife. (*c*) Place the pieces not over 8 inches deep in slatted crates; offset the crates in the storage for good air circulation; turn over the layers every 2 or 3 days. (*d*) Twenty-four hours after cutting, pour the pieces from one container to another to separate those that have stuck together. (*e*) Store at 60–70°F. and 85 percent humidity for 10 days for corking-over of the cut surfaces, and then lower the temperature and humidity to prevent sprouting. After the seed is well suberized, it can be stored at least 3 weeks, but it is unwise to plant seed that has been cut more than 30 days.

Seed-Potato Eyes

The eye method of propagation permits shipment by mail at reasonable cost. It has limitations for commercial crops, but for isolated or distant areas when seed must be brought in it has some merit. The seed should have been stored under proper conditions, and it is wise to treat it in a mercury dip before the eye-sets are cut. A "baller" will cut an eye-set at least ⅞ inch deep and ½ ounce in weight. The eye-sets are washed in water or dusted with lime as soon as they are cut. They are packed for shipment in a moisture-proof, tight container, such as a wax-coated carton wrapped with wax kraft paper.

Small Whole Potatoes

Planting small whole seed is cheaper and gives a better stand and higher yield than cut seed, if both are certified stock. But there is a tendency to take for seed the small tubers that go through the grader. One is then likely gradually to eliminate the good stock, because diseased plants produce more small tubers. If certified seed is used, the small tubers need not be rejected. Whole potatoes may be planted earlier, deeper, and

in cooler soil than cut seed. They have a special advantage for the late crop, as they increase the set which is normally too small.

Planting

Seed set too deep or too early, in cold soil, germinates slowly. This allows soil-borne diseases like rhizoctonia and blackleg to attack the plant. But the early crop should be planted as soon as the soil is warm enough for sprouting, so that the crop will make good growth before hot weather. The late crop is usually planted 4–6 weeks later than the early crop.

On the eastern shore of Maryland two crops of potatoes are produced each year. The early crop, e.g., of Irish Cobbler (an early type), is planted in March and harvested in July; the fall crop, e.g., of Dakota Red (a late type), is planted in July and harvested in October or November. Seed for the late crop is held in cold storage to prevent severe sprouting and shrinking before planting time in July.

Types of Planters

The cup-type planter is well suited to handling whole seed, but it is not well adapted to cut seed because the corners on the pieces wedge into the cups and do not fall out when the cup turns over to let them go down the tube. This planter may be used as an assisted feed type, as many as three of them being pulled by a tractor, with a man to correct the feed on each. But a man must be very active to place a seed-piece in each empty cup and so avoid skips and doubles. He is also in constant danger of catching his fingers when the cup turns over into the tube. It is not used as much as formerly.

The picker type takes the sets out of a hopper by means of spikes that are fastened to a revolving vertical disc and drops them down a pipe into the furrow. It requires only one operator. The pickers jab into the pieces and may thus spread certain diseases.

In a third type of planter, the machine distributes the sets to a notched, revolving, horizontal disc which is watched by a man who fills empty notches and removes a set if two get into one slot. When the notch passes over the delivery spout, the set drops through. Both whole and cut seed, if uniform in size,

are handled equally well. The machine is readily adapted to any spacing desired. A shallow covering device which places the seed in the furrow and puts just a little soil on top of it makes it necessary that the sprouts come through only 2 inches of soil instead of the 6–8 inches where the seed is covered with a ridge. The soil around the seed warms up more quickly, earlier germination occurs, and injury from rhizoctonia and blackleg is lessened.

Depth of Planting

Planting too deep has much the same effect as planting too early; the soil is likely to be cold, germination is slow, and certain diseases are encouraged. The tuber-producing stolons form above the seed-pieces. To allow room for the development of a good set of tubers, the depth on heavy soils may be about 2½–3 inches and on lighter soils 3–4 inches. The early crop is often planted only 2 inches deep. Katahdin is planted deeper than most varieties because it sets shallow and tends to sunburn.

Spacing

Common commercial spacing between rows is 34 inches for the early crop and 36 inches for the late crop. Close spacing (24–28 inches) usually gives a higher yield than wide spacing (42 inches), which is significant for small plantings. Most commercial equipment cannot be adjusted to rows closer than 34 inches. Usual spacing in the row is 9–14 inches for early types and 18 inches for the late crop if 1–1½- and 2-ounce pieces, respectively, are planted. With close planting of early potatoes the plants may shade the soil and prevent too high soil temperatures while the tubers develop. Some varieties, e.g., Rural, Katahdin, and Sequoia, should be planted not more than 9 inches apart in the row on fertile soils, or the tubers may become oversize, rough, and hollow. If the demand is for seed stock of medium to small tubers, potatoes grown for seed may be planted closer than those for table stock.

When 1-ounce pieces are used, and spaced 12–14 inches apart in 32-inch rows, 15–17 bushels of seed are needed per acre. With 1½-ounce pieces, the amount will increase by 50 percent. About 17 bushels of seed are needed when 2-ounce pieces are planted

18 inches apart in 36-inch rows; at 12 × 36 inches, 14,520 pieces are needed per acre.

In Virginia,[186] a factorial field design permitted an evaluation of effects and interactions for 30- and 36-inch row spacings, 10-, 15-, and 18-inch seed spacings, and 1,500-, 2,000-, and 2,500-pound fertilizer rates. The seed spacing had the most influence on yield, usually acting independently of row spacing. The largest income came from seed spaced 15 or 18 inches in 36-inch rows and from the 2,000-pound fertilizer rate. The average weight of prime tubers was increased either when the seed was planted farther apart in the rows or when the rows were spaced wider apart. These two factors acted independently on tuber size. But the effect of varying the fertilizer rate on tuber size was less pronounced than the effect from changes in the spacing.

Growers can use closer row spacing with potatoes when weeds are controlled with chemicals. Also, heavier rates of fertilizer application and irrigation are good practices to accompany those of closer spacing and chemical weed control.

Tillage

Cultivation

A well-prepared seedbed is essential. Then weeds must be kept down (see also Weed Killers, Chapter 15). If too much or too deep cultivation is done, the result is more harm from damage to the roots than benefit from the tillage. The chief purpose of cultivation is to control weeds. Cultivating the early crop when frost is predicted may increase the danger of freezing.

The first cultivation is made when the rows can be seen. This is followed by the weeder, perhaps once a week and after each rain with the teeth set 1–1½ inches deep. The weeder should be used in the heat of the day when the vines are tougher and less easily torn. It should always be used in the same direction, so that the plants fall regularly over the row. When the vine growth is too large for the weeder, shallow cultivation is done between the rows.

Potatoes exposed above the soil turn green and may become unfit to eat. Therefore, as the plants mature, the rows are hilled to cover the tubers and prevent them from greening or sunburning.

RIDGES

In irrigated areas tubers may not only come to the surface but may protrude from the sides of the ridge; hence the need for a broad-topped ridge. There must be enough soil on top of the ridge to cover all tubers that develop. The size and shape of the ridge are vital in avoiding sunburn.

The ridges should be formed quite early; otherwise, the plants are damaged through the cutting of roots in the formation of the ridges. When the plants begin to interfere with cultivation, they are "laid up." The last one or two cultivations are made with disc hillers or winged shovels; the hillers probably make the best-shaped ridges. The furrows which carry the water between the ridges must be deep enough so that water does not touch the plants. In the warmer districts it is not wise to ridge before the cool weather of late summer, as more surface is exposed and the soil temperature is increased by high ridges, and they also induce greater loss of moisture by evaporation.

Irrigation

Although the potato will survive and produce a crop on small amounts of water, it responds, as do most shallow-rooted crops, to timely applications. Irrigation is an essential practice in the drier areas.

At Lincoln, Neb., good, irrigated crops of early potatoes remove 15–22 inches of water from the soil; at Scotts Bluff, Neb., late potato crops use 11–18 inches of water.[420] More than these amounts must be applied because of evaporation and seepage from lateral ditches, seepage beyond the range of roots at the head end of the rows, and runoff at the lower ends of the rows. The amount of these losses depends upon the efficiency of the irrigation practiced, but at best they may amount to 20 percent or more of the water actually used by the crop. Therefore, when water is applied efficiently, 18–25 inches of irrigation water at a pump or head gate should be adequate for high yields of early crops and 14–22 inches should suffice for late crops.

If the soil is dry it is better to irrigate before planting than just before emergence. If fall-plowed land is worked down early in the spring, adequate moisture for germination usually prevails. For spring plowing, the land in the drier areas should be

irrigated or "flooded" first. This usually provides enough moisture for germination. Usually water is not applied until 3–5 weeks after planting or until near bloom.

Sandy soil needs more water than heavier soil. Organic matter in the soil increases the water-holding capacity and reduces the needs for water. More water is required in hot, clear weather than in cool, cloudy weather.

One guide as to the need for water is to dig into the row to about 6 inches below the seed-piece. When squeezed, the soil at

FIG. 59. A large stream of water is flushed through the furrows at the beginning of an irrigation and is subsequently reduced to a trickle. The head-ditch in foreground supplies the furrows between the rows of plants.

this depth should form a ball that retains its form when pressure is relieved and leaves the hand slightly moist. Wilting of plants in midday is not necessarily an indicator. The potato is a cool-season plant, and its root system is not large enough to take care of excessive transpiration from the vine in hot weather. The appearance of leafy shoots from the sides of the ridge is generally caused by high temperatures rather than by mistakes in irrigating. The stolon, instead of forming a tuber, keeps growing and emerges from the ridge as a leafy shoot because of high temperatures.

The water should not run after the "sub" reaches the shoulder of the ridge. Too much water is as bad as, or worse than, too little—growth is checked; in warm weather fusarium attacks plants that get too wet; the soil packs; culls are increased; the tubers do not get air; the lenticles enlarge and turn white; and quality and appearance are reduced.

One inch of water will just wet the soil a few inches at the surface. Frequent applications would cost too much on large plantings and cause too many weeds. A 5-inch irrigation is a thorough one but is not heavy enough to swamp the land. Because sands, gravels, and sandy or gravelly loams are not able to retain 5 inches, 5–8 lighter irrigations usually are better.

The rows are best sloped enough so that the water will run readily without causing much washing. A good head of water should be used, and the head ditches should be near enough to permit the water to run quickly to the bottom of the rows, especially on sandy loams or other porous soils. It is wise and saving of water to start at one end of the field and work to the other, allowing the water that has passed through the furrows of one "run" to pass into a few furrows on the one just below. Runs over 800 feet are too long, as the upper end becomes too wet before the lower end is moist enough. When the vines get long they hang into the furrows and impede running the water long distances.

The last irrigation should not be delayed so long that growth is prolonged late into the fall and harvesting in damp soil becomes necessary. No water should be added later than about a month before harvest. Wet soil makes digging difficult and leaves the potatoes dirty. If water is applied after maturity the tubers may crack or become knobby. Sometimes an eye from the bud end will sprout and 1 or several small tubers are formed at the expense of the original tuber. Such second growth makes the first tuber soft and soggy and promotes a high percentage of small immature tubers. Irrigation should cease in time for the tubers to mature before digging.

Straw Mulching

Mulching is practiced to a limited extent. A weed-free mulch retards the evaporation of moisture and so causes the upper several inches of soil to be moist, lowers soil temperatures (e.g., an average of 7°F. lower at a depth of 4 inches during the summer at Lincoln, Neb.),[420] reduces the daily range of soil temperature, promotes higher temperatures around the plants on sunny days because of the greater reflection of heat, increases yields in dry years, and improves the keeping quality of the

crop. But it may increase the cost of production, delay maturity, cause seed-pieces to decay in a wet season, lower the nitrate supply, and increase the danger of frost; fire is also a hazard. The altering of soil conditions causes the plants to set earlier, fewer, and larger tubers, more free of scab, higher in dry matter and starch, and more intensely colored in red varieties.

The mulch may be such material as hay, cornstalks, lawn clippings, leaves, strawy manure, or straw. It is applied when the first plants emerge. A mulch 1 inch deep is adequate if it covers the entire area, but a heavier covering may have merit.

Vine Killers

Applying a vine killer about 10 days before digging the tubers prevents late-season spread of virus diseases, checks blight spores from being carried into storage, and combats secondary growth. Further merits are that the treatments aid the tubers to loosen from the stolons, give the skin a better chance to mature and toughen in the days between killing and digging, and kill vigorous vines that would clog mechanical diggers.

Good kill is obtained when the vines are sprayed with a mixture containing 1 quart of a sodium arsenite vine killer and 2 gallons of waste crank oil in 50 gallons of water. Several dinitro compounds are useful as vine killers, as is cyanamide. Vine killers sometimes have an adverse effect on the immature tubers and cause a discoloration in the vascular tissues of the tubers.

In New York,[259] the increase in tuber size during late stages of maturity warrant delaying the application of vine killers as long as possible unless greater size is objectionable. Specific gravity readings were lower in vine-killed plots than in controls, the most rapidly killed plots giving lowest readings. Neither killing agents employed nor killing dates affected the value of tubers as a source of seed.

Certain machines permit the use of open-flame burners to kill the tops.

Harvesting

Increase in tuber size continues until the vines die. It is sometimes necessary or most profitable to dig potatoes before they mature, but the skin in these unripe tubers is thin and rubs off easily, and there is some loss in yield.

Digging and Picking

Most small plantings are dug by hand with a potato fork or hook. In larger fields, a turning plow or plow digger is often used to separate the soil from the potatoes partially and to facilitate picking. For commercial crops, the elevator digger is efficient. The blade of the digger passes under the hills, and the elevator or carrier chain carries the tubers up and shakes off the dirt, leaving them on top of the ground; 3–5 acres can be harvested in a day with a digger and a good crew.

To avoid mechanical injury: [387]

1. Dig mature potatoes when possible.
2. Select a digger wide enough to harvest the potatoes without cutting them.
3. Set the digger blade deep enough to avoid cutting, and keep it in the middle of the row. Moist soil should not be allowed to collect on the wheels, as this tends to lift the blade.
4. Carry enough soil over the chain to keep the tubers from bouncing around on the iron rods. If the soil passes too rapidly through the chain, replace the elliptical agitators under the chain with rollers. Slowing down the speed of the elevator apron also prevents too rapid separation and resulting mechanical injury.
5. On loose soils it is helpful to convert the two aprons into a continuous unit or chain.
6. Diggers can be improved by covering the shaker attachment with rubber hose and the sides with canvas. The ends of the rods or hooks on the chain can be covered with a light steel plate or old inner tubing bolted to the frame above the apron.
7. A pair of revolving discs placed on each side of the digging blade can be adjusted to throw the tubers on the outer edge of the row, along with vines and dirt onto the elevator chain.
8. Line picking baskets with burlap. Do not throw, drop, or walk upon freshly dug potatoes. Be careful in running them over the sizer.

Potatoes are easily bruised if picked immediately after being thrown out by the digger. Less bruising occurs if they are left on top of the ground for 1–3 hours or longer. This respite allows the tuber to dry and the skin to toughen and reduces the amount of soil carried into the cellars, but it is not always possible and if the sun is very hot sunscald may result. Frosty nights may also preclude leaving potatoes lying out over night.

Before early potatoes are dug they are cooler than the surface temperature, but when laid on top of the soil on a hot day they absorb heat. When potatoes are slightly immature at digging time, the surface is moist and will skin easily. Therefore, they

may be left on the ground 10–15 minutes to dry off. Freshly dug, immature potatoes may be injured by exposure to sun and heat, if the temperature of the potato tissue reaches 110°F., and thus become susceptible to soft rot and rapid breakdown during storage or shipment.

The sides and bottom of picking baskets should be padded. Tubers are not only injured by the baskets themselves, but also by falling on other tubers. Emptying from the basket into a sack may cause even more damage than picking up. The pickers should not dump potatoes into sacks from an upright position but should carefully roll them into the sack, especially when putting in the second basketful.

Sunscald

Growers often market early potatoes that look sound, but the buyer soon complains that many tubers have broken down. Sunscald injury is not detected when tubers are picked up soon after digging; it develops 18–36 hours later. It first appears in limited areas, $\frac{1}{8}$–$\frac{3}{8}$ inch deep. The skin over the injured areas is watery in appearance, with a narrow, darker area around the margin. Storage at 60°F. checks sunscald and also helps heal skinned and injured tubers. In sunburn due to prolonged exposure to light the skin and flesh of the exposed tubers turn green, so that they are unfit for table use.

Digging after Frost

If potato vines are frosted before the tubers are mature and if the tubers are dug immediately, feathering of the skin may result. Potatoes on freshly frosted vines on muck should not be dug for 10–14 days. This allows the skin to set.

Sorting and Grading

Sorting in the field may be done if the potatoes are well matured or are to be shipped from there. The sorter must be well padded at all places where the tubers strike and must not be shaken when pickers empty baskets onto the screen. The baskets must be emptied carefully. Pads are placed under the sacks on the sorter to prevent bruising the first tubers which drop into the sack. The sacks must be filled well and sewed tightly.

Good sizing machines are those with revolving chains or belts with meshes of different measurements. The tubers are run over the chains or belts, which separate them into the various sizes. Defective ones are picked out by hand. In the roller picking table, the rollers turn the tubers so that all sides are readily seen. Tubers that are brushed should be mature so that the skin does not rub off and should be dry so that the dirt brushes off readily. Submerging potatoes in water, especially deep water and for a comparatively long time, may force the entrance of moisture and bacteria into the lenticels and favor soft rot infection.[105]

Containers

Potatoes are commonly shipped in burlap or solid paper sacks, mostly in the 100-, 75-, and 50-pound sizes. An increasing volume of late potatoes is put up in consumer-size units, usually 10- and 15-pound solid paper, cotton, or open-mesh bags, although some fiberboard boxes of these sizes are occasionally used. Many of the paper bags are made with film or textile "windows," which afford the consumer some opportunity to inspect the product before buying.

Storage

Physiological Changes

Three major physiological phenomena must be considered in relation to storage: (*a*) the development of periderm after injury or when tubers are harvested while immature (rapid periderm formation is an effective barrier to fungal and bacterial infection, and it affects the rate of water loss); (*b*) the starch-sugar system which is affected by temperature and by the ontogeny of the tuber (a high-starch, low-sugar tuber is usually desirable); (*c*) the prevention of sprouting over long storage periods.

Periderm formation. The tuber can lay down quickly a periderm resistant to microorganisms if the tissue is at 60–70°F. The time needed to form adequate periderm at these temperatures varies with the variety, season, soil, maturity, and air humidity. Usually an effective periderm is formed in 2 weeks or less if the air humidity is high. Periderm formation is progressively slower to 40°F.

Starch-sugar balance. Sugar concentration at harvest varies with variety, maturity, season, and soil. The trend of the starch-sugar balance is influenced by the initial amounts present, but usually a tissue at 50°F. will keep a low sugar content for a period which is ended by sprouting of the tubers. Lower temperatures result in higher sugar content.

Sprouting. About 2 weeks after harvest a potato is in a physiological condition (rest period) that prevents sprouting under ordinary circumstances. The length of the rest period is influenced by variety, maturity, soil, season, and temperature. After the rest period the tuber normally will sprout if the tissue temperature is high enough.

In New York,[157] of a total shrinkage of 5.51 percent for 4 months of storage, 75 percent was caused by moisture loss, 25 percent by sprouting. Shrinkage due to sprouting was primarily a function of temperature, whereas shrinkage due to transpiration was primarily a function of relative humidity.

Storage Conditions

Any recommendation concerning storage conditions must be based on a series of compromises devised to fit the environment to the potential changes which may occur in the tuber. A tissue temperature of 40°F. and a low rate of evaporation (controlled by high air humidity) best meet the needs for long storage.

Most potatoes are stored in bulk in some form of common storage. Unless the storage is carefully managed the tissue temperatures may vary greatly over a period of time and even at one time at different locations in the storage. Such storages depend largely on controlled ventilation for the maintenance of desired temperatures. If ventilation is not controlled, or if the outside air remains warm too long, temperatures cannot be satisfactory. Moreover, if the potatoes are piled too deep biological heat will raise the temperature of some of the tissues. It is usually wise to use false walls and floors to facilitate air circulation and heat removal and to construct the bins so that no potato is more than 6 feet from circulating air (see Blackheart later).

A system of automatic ventilation controls has been devised at the Ontario Agricultural College, Guelph, Ont., which, economically, makes optimal use of naturally refrigerated air in the fall-to-spring period in common storages. The system eliminates

most of the irksome and continuous attention needed to manage a common storage, and it makes possible temperature control which is much more uniform than that ordinarily obtained from manual operation.

Chemical Control of Sprouting

A few sound apples in each bushel of stored potatoes may delay sprouting without preventing sprout growth after the apples are removed. Sprout growth can also be retarded to a certain extent by: disinfecting the seed potatoes (for scab, with hot formaldehyde); placing the tubers in shallow piles and turning them in the spring; running them over a potato sorter; storing them at low temperatures; or storing in bags, providing ample circulation around the bags, and turning the bags at regular intervals.

One way to retard the growth of sprouts for a number of weeks and to reduce loss of weight in storage is to spray or dust with methyl ester of alpha naphthaleneacetic acid (Mena) before sprouting begins at the rate of 1 ounce per 30 bushels of potatoes, or to scatter saturated shredded paper throughout the bin of potatoes. If too little is used the effect is short; if too much is used, the tuber may blister. The material is useful only for table stock, not for seed potatoes.

In New York,[116] the material was sprayed, at 3,500 and 7,000 ppm. concentrations, on plants in the field on July 17, August 19, and September 11. The July spray reduced both yield and specific gravity of the tubers. Sprouting in storage was best controlled by the July spray, but the August spray reduced sprouting compared to the check. No inhibition was associated with the September spray. Treated tubers respired less after sprouts developed and contained less reducing sugar than did the checks. The material was as effective at 3,500 ppm. as at 7,000 ppm., and so a still lower concentration might be good, especially early in the season. No difference was subsequently found between yields from treated and check tubers when they were used as seed. 2,4,5-Trichlorophenoacetic acid also will retard the sprout growth.[362]

An aqueous spray of maleic hydrazide, 1,000 ppm. 4–6 weeks before harvest, or 2,500 ppm. 2 weeks before harvest, greatly retards sprouting in storage.[435] The effect of this chemical is

probably due to a reduction of enzyme action and respiration. A small amount of detergent is used as a sticker.

Water Submersion

Flooding of seed potato storages for a few days in spring sometimes occurs. Conditions affecting damage to submerged potato tubers may include the duration of submergence and the temperature, oxygen content, and purity of the water. Stagnant water is more likely to damage submerged tubers than well-aerated water.

Dormant tubers of both Katahdin and Sebago were submerged in water for 10 days at 40°, 50°, and 70°F. and subsequently given the green-sprouting test to determine any damage to their seed value.[158] At 70°F. or room temperature, dead eyes and sunken, decayed lenticels were generally present on tubers submerged more than 3–4 days. This damage is ascribed mainly to the fact that bacterial action is favored by the higher temperature. In appraising possible damage to tubers subject to flooding, it appears that the temperature of the water should be the first consideration. The exact threshold temperature is apparently between 55°F. and 65°F.

Specific Gravity

Potatoes sink in water because they are heavier than water. Adding table salt to water makes it heavier, and some potatoes will then float. These are the nonmealy or less mealy ones. By using several containers of suitable size, each with a different concentration of salt solution, it is possible to separate an entire lot into groups of nonmealy, slightly mealy, mealy, and very mealy potatoes.

For a quick differentiation one solution may be used.[359] Potatoes that float at specific gravity 1.080 (22 ounces of common salt in 11 pints of water) are not mealy. Those that sink at 1.080 are mealy. There are some differences between varieties.

The following terms express different degrees of mealiness: "Bakers," specific gravity above 1.080; "Boilers," between 1.070 and 1.080; and "Fryers," below 1.070. It is possible that consumers would prefer, and would pay more for, potatoes separated as to specific gravity over nonseparated potatoes of the same type.

Insect and Disease Control

Colorado potato beetle adults are large, striped beetles. The red grubs eat the foliage. DDT is applied when the first eggs are hatching or at the first signs that the grubs are feeding. Another application in 10–14 days protects the foliage from grubs that emerge later. The second generation begins to appear in 3–4 weeks, often making it wise to give two or more further applications.

Potato leafhopper feeds by sucking plant juices and, worse still, transmits a substance that causes *hopperburn*. The leaflet turns yellow first at the tip and then around the margin, and the yellowing gradually spreads toward the midrib. The dead parts eventually curl up and become brown and brittle. DDT plus a fungicide is an effective control if applied when the hoppers appear and repeated at 2-week intervals.

A. Diseases affecting plant tops.[110]

1. Leaves yellow, or with dead areas, and rolling or wilting.
   (*a*) Lower part of stem black; seed-piece rotted: *Blackleg.*
   (*b*) Cut vascular bundles brown, oozing white slime: *Brown rot* (*Bacterial wilt*).
   (*c*) Dead areas between veins and along margins: *Ring rot.*
   (*d*) Stem firm; inner tissue brownish up to soil surface: *Verticillium wilt* or *Fusarium oxysporum wilt.*
   (*e*) Internal flecking of stem; stem-end rot or vascular discoloration of tuber in field: *Fusarium eumartii wilt.*
   (*f*) Young leaves not enlarging normally; in red varieties, base of leaflet reddish purple; side shoots swollen at base; brown flecks in pith of lower part of stem: *Purple-top wilt.*
2. Leaves with dead areas but no wilting.
   (*a*) Dead spots with concentric rings on leaves: *Early blight.*
   (*b*) Brown-black, fast-spreading leaf spots; dying of leaves and stems; odor in decayed tissue; white mildew on underside of leaves: *Late blight.*
   (*c*) Inward drying and scorching of leaves: *Tipburn and hopperburn.*
   (*d*) Small dead angular patches on leaves; veins with black streaks beneath; leaves drooping or dropping off: *Rugose mosaic* (current season infection).
3. Leaves rolling, usually soft or leathery; side shoots swollen at base; no wilting, or wilting only late in the season.
   (*a*) See 1(*f*): *Purple-top wilt.*
   (*b*) Basal rolling or cupping of young leaves; rolled parts often purplish; plant with pyramidal shape; aerial tubers: *Psyllid yellows.*

(*c*) Lesions or dead areas on underground stems; leaves soft; enlarged nodes on stems; slight whitish growth on stem just above soil line; black sclerotia on tubers: *Rhizoctonia canker* (*Black scurf*).

(*d*) Lower leaves leathery; plants yellowish green and dwarfed: *Leafroll.*

(*e*) Leaflets stiff, pointed, slightly yellowish; swelling at nodes; tubers lacking, or few and close to stem: *Haywire.*

4. Mottled leaves; yellowish or pale-green spots interspersed with normal green of foliage; slight dwarfing of plant; no wilting.

(*a*) Yellowish and green leaf mottling; leaves slightly crinkled: *Mild mosaic.*

(*b*) Mottled areas smaller than in mild mosaic; veins of lower leaves with dead streaks or areas and brittle; leaflets crinkled: *Rugose mosaic.*

(*c*) Leaves with large irregular cream patches: *Calico.*

5. Leaves small, velvety; stems numerous, spindling; plant dwarfed; tubers small, abundant: *Witches'-broom.*

6. Side shoots forming a sharp angle with the stem; stiff, erect look; leaves slightly rolled and dark green; tuber stem end pointed: *Spindletuber.*

7. Small swellings on roots; some tubers in hill showing pustules and, under them, internal brown spots with small pearly white centers: *Root-knot* (*Nematode gall*).

8. Leaves yellow; shoot dying from tip downward; rusty specks in pith, outer layer of upper part of stalk, and in tubers; tubers small, often cracked: *Yellow dwarf.*

B. Diseases affecting tubers.

1. Spots, eruptions, or cavities on tuber; interior normal or showing blotches or discolorations; no rot.

(*a*) Hard black-to-brown particles adhering firmly to tuber skin: *Rhizoctonia canker* (*Black scurf*).

(*b*) Brown, rounded or irregular, corky, rough spots on tuber: *Common scab.*

(*c*) Spots circular, blister-like but later breaking open and exposing a powdery mass of spores edged by fringed remnants of skin: *Powdery scab.*

(*d*) Warty, cauliflower-like outgrowths at tuber eyes; turning brown-black after decay sets in: *Wart.*

(*e*) See *A7: Root knot* (*Nematode gall*).

(*f*) Irregular brownish stained areas on tuber skin, which turn silvery and show many fine black points when moistened: *Silver scurf.*

(*g*) Soft, pustule-like swellings filled with cream-colored cell growth; hardening and turning brown: *Enlarged lenticels.*

(*h*) Slight pustules or narrow furrows, with slivers of corky tissue under pimples, penetrating ¼–1 inch into tuber: *Flea beetle injury.*

(*i*) Dark sunken areas, sometimes surrounded by raised borders of a gun-metal hue; yellow discoloration in tissue beyond edge of spot: *Early blight.*

(*j*) Brown vascular ring: *Fusarium oxysporum wilt* or *Verticillium wilt.*

(*k*) Brown vascular ring; brown spots in flesh: *Fusarium eumartii wilt.*

(*l*) Brown-black vascular tissue at stem end (shallow): *Stem-end browning.*

(*m*) Brown, fibers at stem end (deep); vascular ring not affected: *Net necrosis.*

(*n*) Brown vascular ring and outer flesh: *Heat and drought necrosis.*

(*o*) Scattered dry, brown spots or blotches in tuber: *Internal brown spot.*

(*p*) Discoloration of interior of tuber; blackening of the water vessels and the finer strands extending into the pith and outer tissues; or irregular patches, gray to sooty black in vascular ring and outer flesh: *Frost or freezing necrosis.*

(*q*) Outer skin and flesh green, underlying flesh yellow; tuber becoming watery and brown: *Sunscald.*

(*r*) Irregular black, leathery area inside tuber: *Blackheart.*

(*s*) Irregular central cavity, lined by a thin brown layer: *Hollowheart.*

2. Rots on or in tuber.

(*a*) See *B*l (*q*); often followed by bacterial or fungal rot: *Frost or freezing necrosis.*

(*b*) Decay brown, ordinarily shallow but may spread through flesh: *Late blight.*

(*c*) Sunken, brown, firm rot, often involving much of tuber; affected part wrinkled; bluish or white protuberances: *Dry rot.*

(*d*) Center of tuber rotting fastest; cavities filled with a pink powdery fungus; pinkish or white tufts of fungus on wrinkled exterior: *Powdery dry rot.*

(*e*) Surface of decaying tuber covered with white fungus threads and brownish, hard, round, seed-like bodies; interior showing a white, odorless decay but later becoming liquid: *Sclerotium rot* (*Southern blight*).

(*f*) A jelly-like rot at stem end of long potatoes: *Jelly-end rot.*

(*g*) Internal tissue granular and watery; when cut may be turning black; if pressed a yellowish-brown liquid given off; external tissue firm: *Leak.*

(*h*) Rot white or buttery; turning black and slimy; foul odor: *Blackleg.*

(*i*) Rot in the vascular ring, creamy, yellow or reddish brown, crumbly or cheesy, odorless, extending later into inner and outer tissue; reddish-brown external effect; tubers often cracked: *Ring rot.*

(*j*) Bacterial ooze and dirt sticking to tuber eyes; vascular ring dark-brown; brown strands, drops of sticky white exudate when cut; slimy soft rot later: *Brown rot* (*Bacterial wilt*).

3. Tubers or sprouts abnormal in shape, but free from spots and rots.

(*a*) Sprouts abnormally slender and feeble: *Spindling sprout* (*Hair sprout*), *Witches'-broom, Leafroll.*

(*b*) New potatoes instead of sprouts on old tuber: *Sprout tubers.*

(*c*) Long tubers spindling, elongated, and pointed at stem end; oval tubers elongated, tending to be blocky-cylindrical: *Spindletuber.*

(*d*) Second growth, or knobs on tubers, easily broken off: *Second growth.*

Virus and Virus-like Potato Diseases

To control *Rugose mosaic, Mild mosaic,* and *Leafroll,* plant only certified seed or resistant varieties.

Spindletuber is transmitted by various insects, e.g., grasshoppers, flea beetles, tarnished plant bugs, and Colorado potato beetles (which should be combatted), as well as by contact with cut seed-pieces, by seed-cutting knives, and by picker planters. Only certified seed should be planted. Tubers selected from plants with strong normal sprouts may withstand *Witches'-broom.*

Yellow dwarf is spread by the clover leafhopper which retains the virus over winter, and so potatoes may need to be isolated from clover. Plants infected with *Haywire* and *Calico* should be rogued out. In *Psyllid yellows* a toxic substance is injected into the potato plant by the feeding of psyllid nymphs; apply DDT. *Purple-top wilt* is not transmitted through the tubers, but the progeny of infected plants lack vigor; no good control is known.

Leaf and Stalk Potato Diseases

Late blight is checked (also *Early blight*) by timely treatments with nabam or zineb. Planting certified seed, disposing of waste potatoes, careful sorting, and seed treatment are helpful. Keswick is highly resistant. Kennebec and Sebago are somewhat resistant. (See also Vine Killers.)

Tipburn is caused by excessive loss of moisture from the leaves during hot, dry weather. *Hopperburn* is caused by the feeding of potato leafhoppers. Frequent use of Bordeaux mixture and DDT helps to control both troubles. The role of DDT in killing leafhoppers is reflected not only in higher yields but also in the improved vigor of foliage and in increased bloom. (See Carbamates.)

Rhizoctonia canker (Black scurf) is checked by planting certified seed. Slightly infected seed should be treated with mercuric chloride if it is to be planted in acid (low-lime) or neutral soils. For an alkaline (high-lime) soil, formaldehyde is better, since mercury may increase scab in such soil. Greening or warming seed tubers, shallow planting, and delaying plantings until the soil is warm, which result in rapid emergence of the plant, and crop rotation, may be helpful.

Verticillium and *Fusarium wilts* are controlled by planting certified seed in noninfested soils, having long rotations, and discarding all tubers with internal discoloration when cut.

Ring rot is very difficult to control. Seed 100 percent free from ring rot must be planted. The cutting knife, potato machinery, containers, and the storage quarters must be disinfected.

Blackleg disease-free tubers, of whole seed or well-suberized cut seed, should be planted. Any condition conducive to heating, such as deep piling, and exposing the seed to flies of the seed-corn maggot, which spreads the disease, should be avoided. Crop rotation should be practiced. Discard tubers with rot or internal discoloration when cut.

Potato Tuber Diseases

Scab is checked by seed treatment with formaldehyde, if the disease is not already in the soil. Since alkaline soils favor scab, it is best to keep soil for potatoes slightly acid. Sulfur, 300–600 pounds per acre, is sometimes helpful on the lighter soils. Russet types are usually free from scab. Ontario, Cayuga, Menominee, and Seneca are resistant.

Silver scurf is checked in storage by low temperature and humidity. Seriously affected tubers should not be planted, and rotations should be long.

Wart is held from spreading by embargo and quarantine restrictions. Green Mountain may be immune.

Storage dry rots are largely caused by *Fusarium* species which enter the tuber through wounds. Careful handling, and cleaning and disinfecting storages are controls. Discarding all wilted tubers and seed treatment help prevent introduction of the parasites into the field. After digging, careful handling and holding for a few days in a warm, moist place so that all wounds may heal properly are helpful. *Jelly-end rot* is a soft rot that starts at the stem end of the tuber. Control is the same as for storage dry rots.

Southern blight in early potatoes is checked by low temperature in storage.

Leak control involves keeping tubers cool and dry during harvesting and loading, as well as in early stages of transit and storage, and avoiding wounds.

Nonparasitic Potato Diseases

Blackheart may occur, especially in large tubers, when oxygen (air) is not sufficient to support normal aerobic respiration in centrally located tissues. Anaerobic respiration occurs, with the formation of alcohol and killing (blackening) of some of the tissues (see under Storage). The tubers should not be left long in hot, light soils after the vines are dead nor be left on top of the soil after digging in hot weather. *Hollowheart* is avoided by producing potatoes of smaller size by practices such as closer spacing.

Internal brown spot may be caused by certain viruses, by deficiency of various elements, and possibly by high temperatures and lack of water during growth. If affected tubers are planted they may give rise to weak plants.

Examining Seed Stock to Eliminate Disease

Tuber indexing. A seed-piece bearing a single eye is planted in the greenhouse in winter (or outdoors in the South) and given a number; the tuber from which it is cut is given the same number and put in storage. When the plants are 10–12 inches high they are inspected for disease. Since both the eye and the tuber have the same number the diseased lots can be discarded.

At elevations less than 1,000 feet above sea level, tuber indexing can be done in the open in Maryland [197] by planting the indexed seed-pieces in March or April, storing the remainder of the tuber at a low temperature, and planting those which have not been discarded in July or August.

Tuber unit seed plot. Each tuber is cut into 4 pieces. These are planted successively in a row, a space is skipped, and 4 pieces from another tuber are planted. Units that show disease are discarded. Few growers maintain a seed plot. It must be isolated, it interferes with the rotation, the machinery must be dragged to two fields, and the roguing is inconvenient. Good results are usually obtained by buying certified seed every 2–4 years, although every year is safer.

Certified seed. Two field inspections, and more if necessary, should be made at such periods as will ensure detection of disease, particularly virus diseases.

Tuber or bin inspection should be made soon after enough time has elapsed for initial shrinkage and for the appearance of storage diseases such as late blight, early blight, ring rot, soft rot, and other storage rots.

Standards of disease and mixture tolerance have been established on a percentage basis in various regions. Fields may be disqualified at any time for any disease, insect, or condition that in the judgment of the inspector is of sufficient danger.

11 · SWEETPOTATO

The sweetpotato is exceeded in volume of production in North America only by the white potato and tomato. It is essentially a crop of warm areas and is grown commercially from New Jersey southward and westward. Louisiana is the leading state in acreage and production. The sweetpotato needs a warm growing season of 4 months between frosts and is very susceptible to frost. It is grown for its swollen, tuber-like roots.

History and Varieties

The sweetpotato is a native of tropical America, where it is called camote or kumara. It was grown in the New World long before Columbus came.

There are two main groups: (*a*) flesh firm, dry and mealy when cooked, such as Little-Stem Jersey, Orlis, Jersey Orange, Orange Little Stem, Rols, Big Stem Jersey, and Maryland Golden; (*b*) flesh soft, moist, and sugary when cooked, such as Nancy Hall, Nancy Gold, Red Nancy, Porto Rico, Porto Rico Unit 1, Cliett Porto Rico, and Triumph. Heartogold is an early variety for shipping. Allgold, released commercially in Oklahoma in 1950, is a "yam" type high in vitamins.

There are two types of Porto Rico, namely, vining (e.g., Porto Rico Unit 1) and bunch (e.g., Georgia Bunch). The vining type has slender prostrate stems and may grow over 20 feet long. The bunch type, which has very short internodes, grows about 2 feet long.

Actually, the "dry" varieties commonly grown in the United States contain a higher percentage of water than the "moist" varieties. It would be more accurate to refer to these two groups as "firm" and "soft." It is not higher moisture content that makes the Porto Rico variety softer, after cooking, than the Big-Stem Jersey, but the character of the solids that it contains. Firm

and soft describe the cooked flesh. When raw, the flesh of all varieties is hard.[41]

Sweetpotatoes that have a moist, soft texture when cooked are often called "yams," perhaps because the term is shorter and more impressive to the housewife. But true yams (*Dioscorea*) are seldom seen on this continent.

Plant Characteristics

The leaves are heart-shaped and measure 2½–6 inches. The long petioles assume an erect position. The small, morning-glory-shaped flowers rarely appear on sweetpotato plants in the United States. Most moist-flesh varieties flower and seed profusely in Puerto Rico, and the Jersey type is not fundamentally different under the proper environmental conditions.[405] In Japan, to induce flowering for cross-breeding the sweetpotato vine is grafted on the moonflower (*Ipomoea bona-nox*).[86]

Propagation

Several types of plant beds may be used, viz., open beds, coldframes, sawdust beds, flue heated, and electrically heated. Manure beds are not advised as manure may spread sweetpotato diseases.

Hotbed Method of Propagation

"Sprouts" or "draws" are broken or slipped from roots planted in sand or other medium in hotbeds. This is the usual procedure in the more northern areas of sweetpotato production. Earlier plants can be produced in hotbeds than by any other procedure, and if a high total yield is desired plants must be set early. Roots kept for seed should be smooth and from high-yielding hills. Small roots produce more plants per bushel than large roots.

Bed medium. Sand is the leading medium. Sawdust beds hold heat longer than soil or sand beds, but are warmed up very slowly by sun heat. Sand beds get hot late in the season unless partly shaded in midday, and they cool down more quickly at night than soil or sawdust beds. The root system of plants produced in sawdust is larger than that in soil, which, in turn, is larger than that in sand. If sawdust is used, the older it is the better; new sawdust is too coarse. Sawdust is more easily transported,

handled in the beds, and steam sterilized than soil or sand. Bedding material should not be used a second time without being sterilized. In preparing a sand bed, a 4-inch layer of sand is leveled over the manure when the heat is obtained from fermenting manure, or 1–2 inches over the bottom of the bed when heating is done with fire. When the sand has become warm the roots are bedded on it parallel with each other.

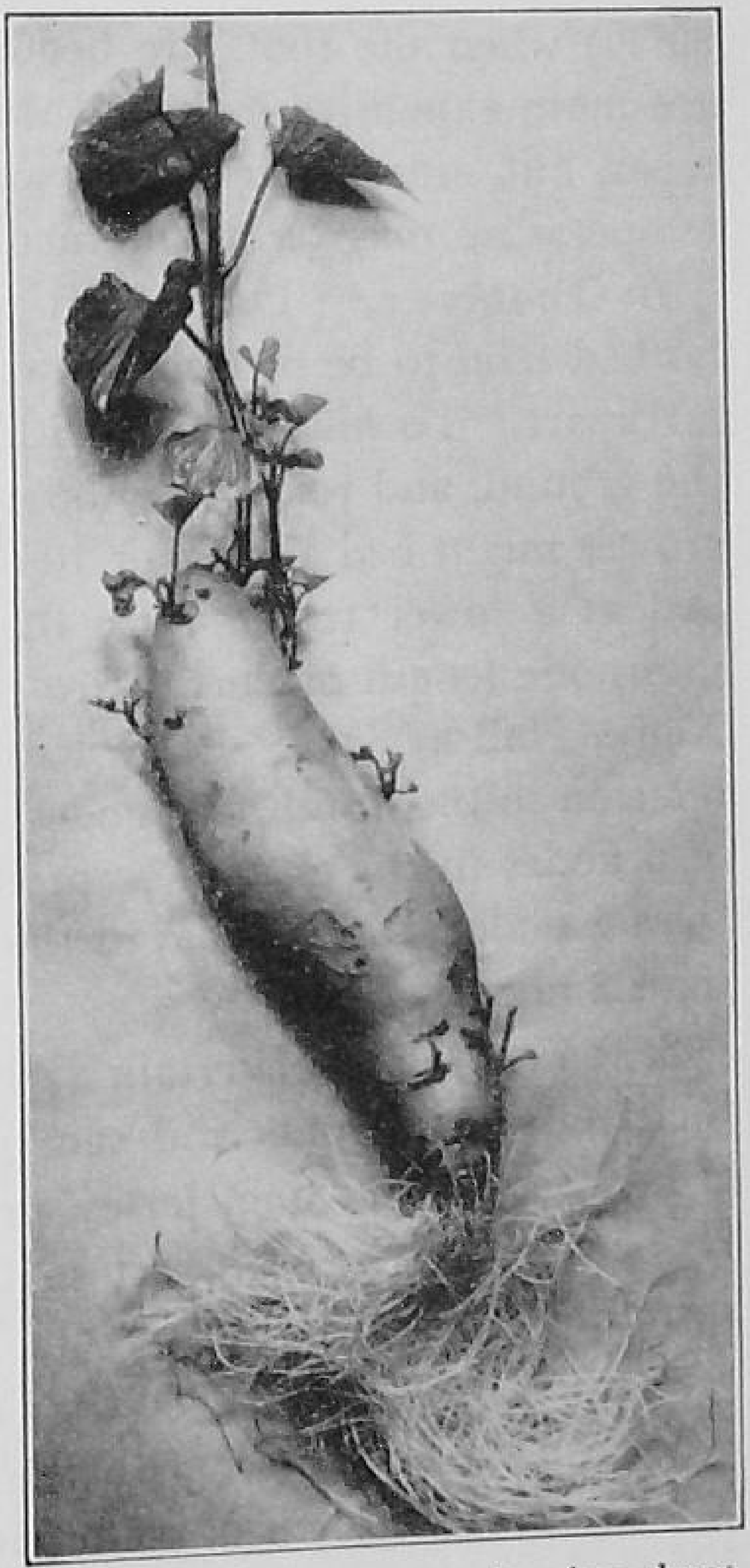

Fig. 60. A sweetpotato showing shoot and root development.

Depth of bedding. The roots are covered with 1–2 inches of sand or other suitable material and watered immediately. Large and small seed-roots should not be bedded together, as the small ones may be covered too deeply. Sprouts emerge in about 2 weeks.

Period to develop plants. A period of 4–6 weeks is needed, to develop the sprouts, from bedding until field planting. The date of bedding should be so timed that the sprouts do not grow too long by planting time. Roots that are starting to grow produce the earliest sprouts in the hotbed. Sprouting from dormant seed stock is hastened by heating the storage to 80°F. and by increasing the humidity for 2 weeks before the roots are bedded.

The seed stock should be bedded[45] in a properly built and operated electric hotbed 4 weeks, and in a fire-heated hotbed 6 weeks, before the average date of the last killing frost. This gives plants for transplanting to the "mother patch" or for setting in the field for the production of early potatoes for the market as soon as all danger of cold weather is over. The manure-heated

hotbeds usually produce plants ready for setting 7–10 days after the artificially heated hotbeds.

Bed heat. Artificial heat should be available in the hotbed from bedding time until the plants are well up. When fermenting manure, or a flue, is the source of heat, the beds are prepared some days in advance so that the medium will be warm (at about 80°F.) when the roots are bedded. Electrically heated hotbeds are more expensive to install than fire-heated or manure-heated types, but, since their heat is automatically controlled, an even temperature may be maintained with a minimum of labor.

In Tennessee,[265] Porto Rico plants, or slips, produced in the hotbed tend to be of rank growth and have the nodes relatively far apart. To have plants with enough nodes to be placed in the ground, and yet not be too cumbersome for field setting, the grower might bed a week or 10 days earlier and operate the hotbed at a lower temperature than is customary. At 75°F. the internode length of Porto Rico plants is about equal to that for Nancy Hall at 85°F. Porto Rico yields U. S. No. 1 potatoes in relation to the number of nodes set in the ground. The placing of 6 nodes in the ground [264] produces more marketable potatoes than 4 nodes, and 4 nodes in the ground results in higher yields than 2 nodes.

Spacing. Roots of certain varieties, e.g., Nancy Hall, produce relatively few sprouts and can be bedded fairly close together. Others, e.g., Little Stem Jersey, produce more sprouts and should be bedded 1–2 inches apart so that the plants do not become spindling.

Amount of roots required. To set an acre requires 10,000–12,000 plants, depending on the spacing. If only one pulling is made 10–12 bushels of seed-roots are needed for an acre. The larger the roots, the fewer plants from a bushel of seed. It takes 5–8 bushels of roots to give enough plants from two drawings of sprouts to plant an acre. About 1 bushel fewer roots are needed when the third crop of sprouts is used. The first pulling is usually the heaviest commercially. A bushel of seed-roots occupies about 15 square feet of bed space.

Sprout quality. Successive pullings can be made at 5–7 day intervals. Draws from first, second, and third pullings are of equal value if of comparable size when pulled. Poor results with

second and third pullings are due chiefly to delayed planting, to the use of undersized sprouts, or both.

Sprouts should be at least 6 inches long before pulling. Those 6–7 inches and 9–10 inches long are equally productive, provided all are sturdy, vigorous, and otherwise of similar quality. A "pull" will sever from the parent root that is held down with one hand. Some roots will be formed already on the stem.

Propagation in Open Beds

In the middle South it is a common practice to produce only enough plants in a plant bed to transplant about a fifth to a third of the acreage to be grown. From this "mother patch" cuttings are obtained for transplanting the rest of the acreage. Where the season is very long, vine cuttings are comparatively cheap. Also, the potatoes are comparatively long, smooth, and small in diameter. Vine cuttings to be stuck deeply in a high, broad bed should be made 10–12 inches long.

In South Carolina,[45] seed stock bedded in "cold beds" from March 1 to March 15 gives "cut sprouts" for transplanting during May. Sprouts or plants to be used as "cut sprouts" should be allowed to grow 1–2 inches taller than usual to take care of the root being cut off.

Near the coast in South Carolina, the "root patch" or field-bedded potatoes, if planted in early spring in rows in the open, are successful in producing early vine cuttings. The purpose is to produce many vine cuttings as early as possible. The procedure is as follows: Select soil that is springy and warms up early. Lay off rows 3½–4 feet apart. Fill the furrows with mule or horse compost, and apply fertilizer. Then bed with 2 furrows, trenching the bed lightly with the foot of the plow. The roots are dropped end to end, 3 inches apart. A second row of roots can be dropped in the same trench by breaking joints of the first row. The roots are covered with 3–4 inches of soil. When sprouts begin to develop on the roots a large sweep or board is used to remove the top 1–2 inches of soil. This practice promotes earlier emergence of sprouts and aids in weed control. About 100–150 bushels of seed stock potatoes will plant 1 acre of "root patch." An acre "root patch" will produce enough vine cuttings to set 10–15 acres.

Propagation from Root Pieces

Sweetpotatoes may also be propagated by pieces of cut potatoes in much the same way as Irish potatoes. But the cut pieces usually result in large, rough potatoes instead of medium-sized ones of better quality.

Disease control. Roots to be used as planting stock should be hill-selected when they are dug, or they should at least be from fields where diseases are not prevalent. Stem-rot-infected potatoes are difficult to recognize in spring when the roots to be bedded are sorted. Badly shriveled or decayed potatoes, or those infected with black rot, soil pox, or other diseases, are discarded. Roots that are to be bedded should be treated with wettable Spergon (1 pound in 5 gallons) or Puratized Agricultural Spray 5 percent (1 teaspoonful in 6 gallons).

Handling roots. "Careful" handling may be said to mean placing roots directly from the row at digging time into crates, and "commercial" handling to consist of throwing roots of 3–5 adjacent rows into a center or "heap" row that is then placed in crates. Carefully handled roots lose less weight in storage, rot less there, and produce more plants both in total and in early pullings. Careful handling lowers the cost of production and the storage and bedding space needed to produce a given number of plants.

Hill selection. Roots for seed stock should be selected in the fall at harvest time. The workmen who remove the roots from the plants can place the better plants with roots still attached in a row by themselves for final inspection by a person competent to select for the type desired and for freedom from stem-rot. Seed stock should be produced so as to be free of all diseases which cause decay losses during storage and low production of plants in the beds. The diseases which cause sweetpotato rots live only on sweetpotatoes, and if this crop is not grown on the land for several years the organisms die.

Color

Typical flesh color can be readily determined by cutting out or "nicking" a small chip not over ¼ inch deep from the shoulder of the potato near the end by which it was attached to the plant. Only those roots with the desired interior flesh color should be bedded. Flesh color also can be determined at harvest by clip-

ping off the stem end of the roots, thus eliminating the necessity of "nicking" at bedding time. This procedure does not materially damage roots for market purposes if they do not meet seed-stock standards.

TEMPERATURE AND NITROGEN [113]

For propagating purposes sweetpotatoes should be: harvested early (well before frost), stored where they can be protected from temperatures below 50°F., and harvested from fields receiving small to medium rather than high applications of nitrogen.

In the warmer parts of the South, where natural temperatures are relatively high, reaching 80°F. or more at the start of the harvest season, there is little if any benefit from a short (5-day), artificial-heat curing treatment upon subsequent sprout production. Roots harvested early under these conditions may be safely stored without applying artificial heat at once, if natural temperatures approach those recommended for curing. But at mid-harvest season or later, conventional curing conditions should be used. In the cooler districts curing is essential.

In growing bedding stock nitrogen fertilizer should be kept to the lowest level consistent with good yields. Excesses should be definitely avoided.

Soil

Contrary to a common belief the sweetpotato is not a poor-land crop. Although it is true that the sweetpotato produces more desirable sizes and shapes of roots on certain soils of medium to light texture than on heavy soils, it can produce profitable yields only on soils of good fertility, i.e., either natural or added in the form of manures and fertilizers.[41]

Land that will produce a bale of cotton per acre is good land for sweetpotatoes. Heavy and very rich soils tend toward too much growth and poorly shaped roots. Plowing commonly is 3–4 inches deep, but 6–8 inches would often be better.

In Mississippi,[228] fibrous roots were concentrated in the top 5 inches in the Ruston soil and the top 12 inches in the Ocklocknee soil. The sparse fibrous root development in the subsoil, especially marked on the Ruston soil, accounts for the quick effect of drought on leaf-shedding and ultimate yield. Storage root development was appreciable in early July and continued until harvest.

Sweetpotatoes do best in a slightly to moderately acid soil, and yields may be somewhat decreased when the soil is neutral or alkaline. Decreases in pox occur with increases in soil acidity. There is no upper limit for the activity of the soil-rot organisms as for the kindred organism of white potato scab.

A rotation in which sweetpotatoes are planted on land only once in 4–5 years is very important for disease control, good production, and maintenance of soil fertility.

Planting

Ridge height is important not only in relation to surface water but also to efficient culture and harvesting of the crop. If ridges are much less than 10 inches high at planting time, the crop may lie so deeply in the soil that an excessive number of roots will be cut, broken, and even lost during harvesting.[41]

The height of bed influences the yield and also the shape of sweetpotatoes. These results, in U. S. No. 1's per acre, were obtained:[45] low bed (0–2 inches), 154 bushels; medium bed (6–8 inches), 197 bushels; high bed (12–14 inches), 201 bushels. Thus plants, "cut sprouts," and vine cuttings should be set on a high, broad bed, and this type of bed should be maintained throughout the season.

Method of transplanting. The sprouts are usually set with a planting machine, but on small areas they are set by hand with a "tong" and "shovel" or dibble; vine cuttings are pressed into the soil with a long, notched stick. Sprouts are planted soon after they are drawn, and water is applied in the furrow as they are being set in order to prevent excessive wilting. A good sprout is stocky and 6–10 inches long. To avoid injury from wind whipping, the planted sprouts should not extend above the soil more than 3 inches.

Three men with a 1-row planter, properly handled, will set 3,500–4,000 plants per hour (1 man driving and 2 men handling plants). With a 2-row planter, 5 men can set 7,000–8,000 plants per hour. By machine 25 plants per man per minute is a reasonably good rate of planting; by hand methods 6 plants per man per minute is good.[41]

Spacing. In some areas the rows are spaced 32 inches apart. It ranges to 42 inches in different areas. A larger proportion and

higher yield of smaller roots result from spacing at 6–9 inches as compared with 12–15 inches.

TIME OF PLANTING. In Louisiana, for the early crop and the production of vine cuttings for the main storage crop, plantings are made as early as the vine supply is available and the danger of frost is over. For the storage crop to be used in the winter and spring, plantings are made from cuttings as follows: South Louisiana, June 1–15; Central Louisiana, May 10–June 1; North Louisiana, April 20–May 20. Early planting produces the greatest yield but more short, turnip-shaped roots. Medium-early planting at the dates given produces a fair yield, more well-shaped roots and a large percentage of No. 1 stock. Late planting produces a low yield and long, stringy roots.

In most sweetpotato areas planting should be done about a month after the *average* date of the last frost in spring, or about 10 days after the "frost-free" date. Successive 2-week delays in planting from May 15 to July 15 in coastal South Carolina result in both a lower yield and a decrease in grade. In eastern Virginia,[8] good bedding and transplanting dates are: *Early crop:* bed March 5 to April 1; transplant April 15 to May 1, or as early as weather permits. *Storage crop and seed stock:* bed April 1 to April 15; transplant May 15 to May 28. In Piedmont and southwest Virginia, for all purposes, bed April 25 to May 5, and transplant June 1 to June 10.

Manure and Fertilizer

The sweetpotato is a good forager for nutrients but is often grown on soils of too low fertility for a high yield. Heavy applications of manure promote excessive growth. Sweetpotatoes may not need so much humus in the soil as many other crops. If both have to be bought fertilizer is likely to be more profitable than manure. Fresh manure causes rough roots. Manure may spread disease.

Fertilizer recommendations are remarkably similar among most of the States where the crop is grown. The most profitable yields have been generally obtained with 1,000–1,500 pounds per acre of mixtures containing 2–4 percent of nitrogen, about 8 percent of phosphoric acid, and 8–12 percent of potash on fields where good amounts of green manures or animal manures have been turned under.

In Mississippi,[229] applications of nitrogen and potassium were associated with the nitrogen and potassium content of the leaf-blade and with the yields of the roots. Plants with leaves containing 4.7–5.0 percent nitrogen in early summer and 3.0–3.8 percent at harvest and with at least 2.0 percent potassium during all stages of growth produced higher yields than those supplied with less available nitrogen and potassium.

In Maryland,[341] the percentage of potassium in the vines decreased during the period of growth of the fleshy roots. Total seasonal intake of potassium by Porto Rico amounted to 541 pounds of potash per acre, of which 362 pounds was present in the roots. Total uptake by Maryland Golden was 256 pounds, of which 152 pounds was found in the roots. Uptake during the first 2 months of the season amounted to about 5 percent of the total. Vine growth accounted for most of the potassium utilization during the third month, whereas accumulation of potassium in the growth of the fleshy roots accounted for nearly all the potassium uptake during the last 2 months of the season.

Broadcasting fertilizer is less suitable than placing it in the row before ridging or in bands beside the row, but heavy applications in the row may be unsafe. Deferred use of all or part of the fertilizer as sidedressings is sometimes best.

Cultivation

Sweetpotatoes are cultivated to control weeds until the vines meet in the middle. A good implement for ridged fields is a single-row corn cultivator equipped with knife-like sweeps about 2 feet long, instead of the two inside cultivator shovels. The sweeps are attached to shanks near their forward point and are connected to the beam with universal joints so that they can be adjusted to any slope. The sweeps slant outward and downward so that the blade skims the sloping ridge just below the soil. They may be tilted so that soil is thrown on the ridge and covers small weeds in the row. The regular shovels are used to cultivate the centers of the rows. A cultivator equipped with these sweeps will destroy weeds after the plants are fairly large without the need of first turning the vines and without mutilating them. To prevent the vines from rooting after they start to run they are sometimes lifted and moved every 2–3 weeks.

Disturbing long vines reduces the yield. Pruning the tips also reduces rather than increases the growth of the roots.

Irrigation

The plants tolerate considerable dry weather, but some supplementary irrigation is often desirable. Water is best applied after the plants are set and before they nearly cover the ground. Light frequent applications are preferable to heavy applications at long intervals, but continuous moisture near the surface promotes shallow roots.

Harvesting

Yields of 200–300 bushels per acre are secured under favorable conditions. The market preference is for 8- to 12-ounce roots.

Sweetpotatoes intended for use during late fall, early winter, and the first half of the next year should be harvested just before the end of a dry spell in late fall while the weather is still warm and before any frost has occurred. Under such conditions the leaves will be turning yellow, the vines making practically no new growth, the potatoes will be nearly mature and cured, and the temperature will not be low enough to chill the potatoes.

A frost that is just severe enough to kill the leaves may not damage the roots, but the roots are injured when the crowns freeze. Roots of plants exposed to a killing frost do not keep well in storage, and their eating quality is impaired. Roots for "seed" or storage must be harvested before any frost occurs. If exposed to temperatures below 40°F. they may not sprout. The roots freeze at 29°F.

In a 3-year test,[103] Triumph and Porto Rico were dug at intervals of 2 weeks starting before the first killing frosts and extending until 8–9 weeks after them. At the time of the first frost killing at least half of the foliage, vine-cutting treatments were applied as follows: (*a*) vines undisturbed; (*b*) vines cut at hill but not moved; (*c*) vines cut at hill and in furrow and raked over row; (*d*) vines treated as in *c* but with soil plowed over vine-covered row. Yields of sound roots usually showed only slight decreases with harvest delays as long as 5–6 weeks after the first killing frost, but serious reductions occurred with delays of 8–9 weeks. Roots harvested more than 2 weeks after frost spoiled more quickly and had less starch and less solids than those harvested at frost or before, and these effects became more serious as the time of harvest was further delayed.

Delays of 5–6 weeks and 8–11 weeks in harvesting Triumph roots caused reductions as high as ¼ and ⅖, respectively, of the amounts of starch present in roots dug before frost. Despite reduced starch percentage following the first frost, maximum yields of starch per acre were sometimes observed 2 weeks after frost because of continued root growth. The maximum content of starch in raw stock was obtained at or before the first killing frost. Vines offered no apparent protection to roots, either when left undisturbed or when raked over the row with or without additional soil coverings. Cutting vines at the hill immediately after frost was of no benefit in preventing rotting or in reducing loss of eating quality of roots when harvests were delayed. The starch content of sound roots left in the ground was not altered by the vine treatments used. Unheated shed storage of roots for 1 week immediately after harvest caused reductions of 1.6–4.4 percent in starch content as compared with freshly harvested stock. Unheated shed storage of Triumph roots for as long as 2 months usually was practical only on stock harvested no later than 2 weeks after killing frosts. Edible quality of Porto Rico roots was impaired by low temperatures resulting from both delayed digging and unheated storage.

The vines on each side of the row are cut before digging, e.g., with two disc coulters (moldboard plow type) attached to a sulky cultivator. When a tractor is used, the cutting coulters are attached to it just ahead of the digger. If mower sickle sections are attached to the two runners of a stoneboat, when it is drawn astride the row they will extend into the soil and cut the vines on both sides of the row.

Common procedure, after the plants are loosened with a digger, is to break the roots from them. Sweetpotatoes may be plowed out, or a U-shaped blade may be drawn under the plants. An inclined steel flange extending rearward is attached to the bottom of the U-shaped blade, to raise the plants so that the roots are loosened and easily removed from the soil. Heavy storage losses due to rots, as well as shriveling, may result when roots are injured. Even though decay does not follow, the bruised places remain evident and may become dark colored, and so reduce the market value.

Probably the best keeping quality is obtained by digging with a 16-inch turning plow. A rod wing middlebuster causes more skinning. Digging with a white potato digger gives poor results, although a digger with most of the shakers removed is fairly satisfactory. Digging with an ordinary middlebuster or a 12-inch turning plow may be rated as giving intermediate results.

After the roots are broken from the plants, they are placed on the row to dry before they are gathered into baskets or crates. The secondary roots, the taproots, and the stem are broken from sweetpotatoes that are to be marketed immediately, but in order to avoid unnecessary injury these are not broken from roots that are to be cured and stored.

Best results in picking up are obtained when sweetpotatoes are picked up directly into the storage crates. Throwing into heap rows is slightly less satisfactory. Leaving overnight when exposed to frost is undesirable. Very poor keeping quality is obtained when the roots are picked up into sacks.

Sweetpotatoes may be injured by exposure to the sun when they are dug in hot weather.[270] But they are not so likely to be injured by sunscald as white potatoes; e.g., an exposure of about 3 hours under severe conditions is necessary in Louisiana to cause noticeable injury. This does not mean that early sweetpotatoes should be neglected at digging time and exposed to the sun during the hottest part of the day. However, it does not seem likely that roots dug in October in Louisiana will be injured by sunscald.

Harvesting should, whenever possible, be done during dry weather, and the roots should be dug early in the day so that they can dry and the skin can harden somewhat before they are picked up. The excess moisture taken into storage with undried potatoes and the soil that adheres when they are gathered while damp are objectionable. If it is necessary to dig the roots after a rain, the mud and dirt are best removed after the roots have dried in storage.

Curing

Curing after digging was formerly thought to be important in removing excess moisture from the potatoes and so was largely considered a process of drying-out of the roots for better storage. The newer viewpoint has led to keeping the roots in a moist atmosphere during curing so as to aid healing and to prevent excessive loss of moisture. Only enough ventilation is given to prevent condensation of moisture on the roots or on the walls in the curing house. The object of curing, therefore, is to heal wounds quickly and hasten the thickening of the skin to give protection against rots.

Healing occurs in 10–14 days if sweetpotatoes are cured at 80–85°F. and 90 percent relative humidity immediately after digging. In fact, curing at 84°F. for 4 days is usually ample with some varieties.

The skin of an uninjured sweetpotato consists of several layers of corky cells that reduce loss of water and effectively keep out rot fungi. When this protective covering is broken, new layers of corky cells to cover the wound are produced if the sweetpotato is in a warm, humid environment. Injury to a root is followed by an exudation of a milky fluid, which dries and hardens. But this does not constitute healing. The walls of a few layers of the exposed cells in the wound next become thickened and hardened and help to prevent evaporation. Surface moisture thus being lessened, rot infection is retarded, because the spores need moisture in order to germinate and grow. Actual healing is due to production of several layers of new cells just beneath the wound. These new cells develop into wound cork, and their outer layers become dry and corky. They resemble the cells of the original skin and serve as effectively in preventing water loss and disease infection.

Ordinarily, artificial heat is needed to secure an effective curing temperature, though roots of Porto Rico can be cured and stored without added heat in southern Louisiana. There, especially in the Sunset area, large crops of sweetpotatoes are stored in warehouse-like buildings, and the roots themselves furnish enough warmth during cold spells to make heating unnecessary; most of the crop is dug in October.

Storage

Temperature and Humidity

As soon as the curing period is over, the temperature of the house is gradually reduced in about 2 days to 55°F. and maintained there. If the temperature is lowered too quickly, moisture condenses in the house and rots may develop. The temperature must not fall and remain much below 50°F. because injury followed by decay results. Storage at 40°F. for 1 week lowers both the keeping quality of the roots and plant production. Slow sprouting may result at 60°F., and the roots may shrivel excessively. A high relative humidity is desirable.

At Beltsville, Md.,[78] Orange Little Stem, Nancy Hall, Maryland Golden, and Porto Rico were cured and then stored at 50°, 55°, and 60°F. Under good sprouting conditions those previously stored at 55°F. and 60°F. sprouted well. Most rot developed during the sprouting period occurred in material that had been stored at 50°F. Also, most of the dormant (nonsprouting) roots were among those stored at 50°F. This information may help to explain certain instances of bedding failures.

Changes during Storage

Sound roots lose 6–8 percent in weight while curing, mostly as free water and partly as carbon dioxide in respiration.

Some of the starch in Little Stem Jersey changes to dextrin and sugars during curing, but much of it remains as starch, which allows the cooked sweetpotato to remain relatively firm and dry. Porto Rico and Nancy Hall contain more dextrin and sugars than starch when they are harvested, and during curing most of the starch is converted to dextrin and sugar; their flesh is moist and soft when cooked. Because newly harvested Nancy Hall roots contain more sugar before being cured, they are then generally considered more palatable than starchy varieties like Little Stem Jersey. For this reason, Nancy Hall is commonly grown for early-fall marketing, though it is equally suitable for storing.

Containers

A special wirebound crate, designed to provide proper ventilation, is now widely used for shipping. The outside width and length are the same at top and bottom, but the upright end slats are attached in such manner that the inside length is somewhat larger at the bottom than at the top. The inside dimensions are, in inches: depth, 11⅝; top, 13⅜ × 14$\frac{9}{16}$; bottom, 13⅜ × 16. The crate delivers 50 pounds net weight. Some areas ship sweetpotatoes in 1-bushel tub baskets or 1-bushel hampers. For local distribution and immediate consumption, 50- and 100-pound burlap bags are commonly used.

Insect and Disease Control

Sweetpotato beetle (several species) eats holes in the leaves of newly set plants. A stomach poison provides control. Before

transplanting, the plants may be dipped in an arsenical solution.

Sweetpotato flea beetle eats long, narrow grooves along the veins. Rotenone is a control.

Sweetpotato weevil grubs tunnel in the roots and vines. Controls are: planting uninfested roots and plants or slips; keeping plants well hilled with soil; and, after harvest, destroying plants and tubers that are infested.

Stem rot or *wilt* infected plants produce short, rosette-like stems. The youngest leaves show the disease first but persist until the plant dies. The oldest leaves fall soon after the fungus attacks the petiole. The fibrovascular bundles of the vines become black. Roots from diseased vines should not be planted. Phygon (2 ounces per gallon of water) is effective as a seed-root (dip them momentarily) and sprout treatment. Resistant varieties should be grown in rotation.

Black rot shows, in early stages, yellowish, sickly foliage and black cankers or spots on the underground parts of the stem and the potatoes. Under these spots is a rather dry, black, fungus decay of the flesh, which may increase in storage. Infected roots are bitter and should be discarded. Treat as for stem rot.

Pox results in malformed and pitted, fleshy roots and in decay of the rootlets of the plant. Heavy applications of sulfur to the soil may be helpful in some cases.

Foot rot, in the seedbed, causes a stunted, sickly growth or, if severe, death. The fungus grows from the stem into the roots, and roots may be found in all stages of decay when they are dug in the fall. Disease-free seed should be selected, treated as for stem rot, and rotated with other crops.

Scurf shows as an irregular, brownish discoloration on the roots. It can be easily scraped off by the finger nail. Scurf-free roots should be selected, treated with Spergon, set in a clean seedbed, and rotated with other crops.

Soil rot causes small, thin, pale-green leaves. The root system is poorly developed and is marred with spots. The lesions at first are covered by the root skin, which later breaks away, exposing a cavity. Soil rot is not spread from seed potatoes to the plants produced therefrom. Crop rotation is helpful.

12 · SOLANACEOUS FRUITS

TOMATO

The tomato ranks second in value among vegetable crops grown in America, being exceeded only by the potato. Its popularity is due to the pleasing acid taste (which is largely retained in manufactured goods), yield, cheapness, and health properties. Tomatoes may yield 15–20 tons per acre, but 7 tons is a fairly good yield.

The farm value of the tomato crop in the United States and Canada is about 200 million dollars annually, from about 1 million acres. About one-third of this acreage is used for growing tomatoes for the fresh market, the remaining two-thirds of the crop being produced for canning and manufacture into tomato products. Production for the fresh market is about 40 million bushels annually.

History

The cultivated tomato originated in Mexico.[199] But since all the wild species are confined to the Peru-Ecuador area it is assumed that the ancestral form migrated in pre-Columbian times, probably as a weed, to Mexico, where it was domesticated and improved. Field observations have established a center of varietal diversity of the cultivated tomato in the Veracruz-Pueblo area of Mexico.

Probably the earliest mention of the tomato by European botanists is in the herbal of Matthiolus, 1554, who says it had recently appeared in Italy and was known as *pomi d'oro* (golden apple). In the seventeenth century, it was still grown in England for ornament only, though it was known to be eaten elsewhere. By the end of the eighteenth century it was grown on a field scale in Italy for food, but it was half a century before people

on this continent dared to eat it. Less than 100 years ago, it was thought to be the cause of various ills, such as cancer.

Some of the earliest varieties imported from England and France were Tree, Fiji Island, and Cook Favorite. Most, if not all, large-fruited varieties were selections from Large Red or the ribbed type that had been known since 1550. Tilden originated in 1865 as a chance seedling at Davenport, Iowa, and was the

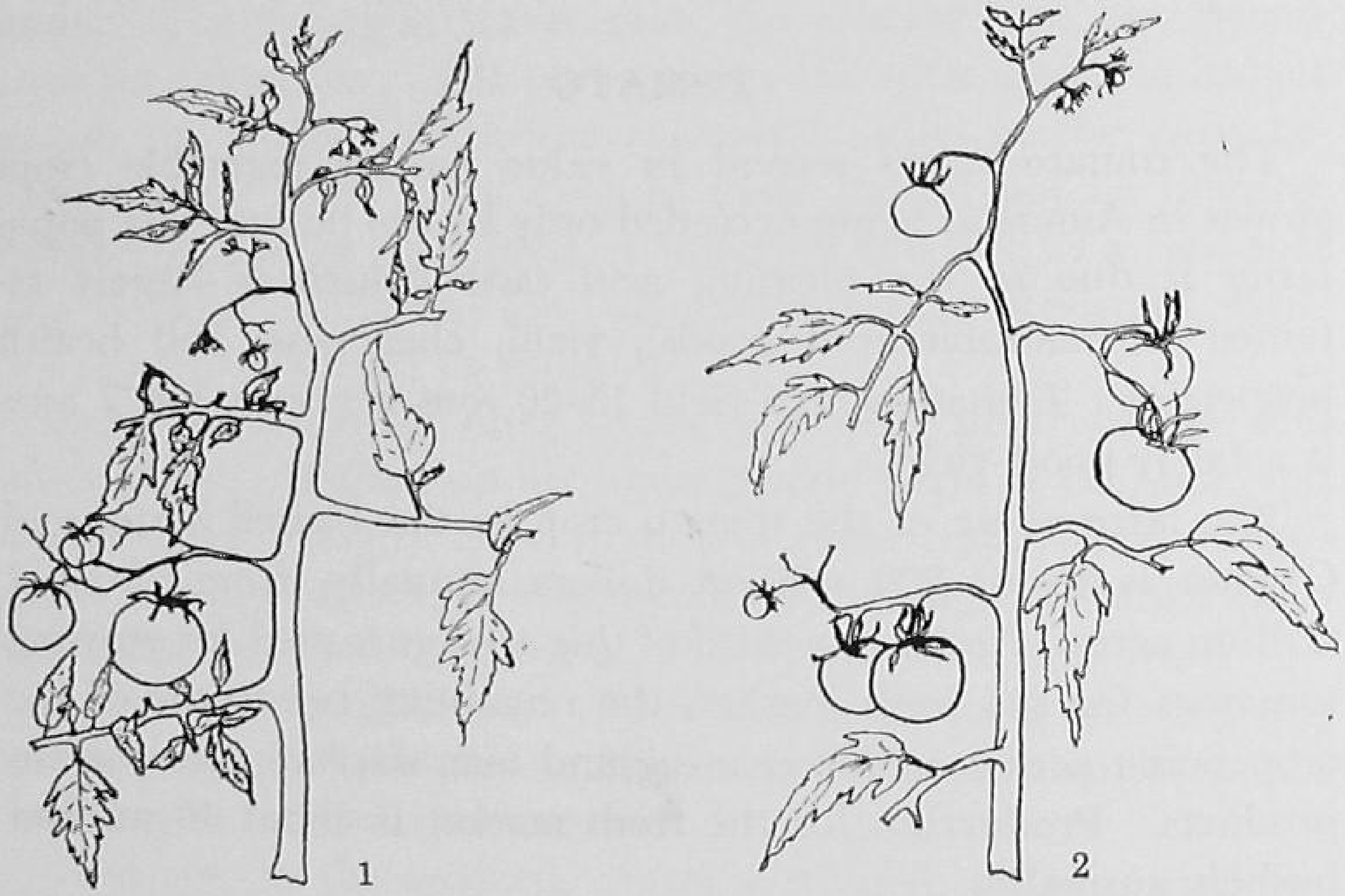

FIG. 61. Tomato, indeterminate and determinate types.

first American contribution to tomato improvement. The next notable advance was Trophy, which a Dr. Hand in Maryland originated from crossing and selection.

A. W. Livingston, Columbus, Ohio, and his associates and successors originated a worthy list of varieties. Of about 40 varieties that attained a distinct status prior to 1910, a third were Livingston introductions. If we add varieties derived directly from these, about half the major varieties are attributable to the abilities of the Livingstons to select superior material, e.g., Paragon, Acme, Perfection, Golden Queen, Favorite, Beauty, Potato Leaf, Stone, Royal Red, Aristocrat, Buckeye State, Honor Bright, Magnus Dwarf Stone, and Globe.

Cooper Special, a determinate type, was developed by a Dr. Cooper, Fort Lauderdale, Fla., and introduced about 1923. Dr.

A. F. Yeager, in North Dakota, used Cooper Special in developing very early determinate varieties. A cross of Red River × Cooper Special was made in 1925; from it came Viking, Fargo, Bison, Bounty, Victor, and some others. Early Chatham, another Yeager origination, was developed at Chatham, Mich.

All-America winners are: 1933, Pritchard; 1935, Scarlet Dawn; 1936, Burpee Globe; 1938, Cardinal and Harkness; 1940, Mingold; 1941, Victor; 1943, Jubilee; 1949, Wisconsin 55; 1951, Urbana. In this same period a number of other varieties, which became commercially important, were introduced, namely, Rutgers, Garden State, Red Jacket, Gem, Longred, Southland, Summer Prolific, Fortune, and Jefferson.

Some years ago Marglobe, Martin Stone, and Jack of Hearts were the leading shipping varieties in California. They were largely displaced by Pearson (a selection of San Jose Canner × Fargo). In 1948 the J. Moran variety (Improved Pearson × Morse 133-6) was introduced by the Ferry-Morse Seed Co.; it compares favorably with Pearson in California.

Classification and Varieties

A. *Indeterminate (standard).* Plants capable of continuing their growth more or less indefinitely; normally, a blossom cluster is produced at every third internode, being separated by 3 leaves.

1. *Earliana.* Immature fruits green streaked; mature fruit $4\frac{1}{2}$–$5\frac{1}{2}$ ounces, deep oblate or flattened-globe shape with a slight tendency to be pointed, corky ring inconspicuous, stylar scar medium, cells 10–12, cell arrangement irregular; lacking in uniform ripening and coloring; circular cracks common, radial cracks rare; plant sprawling, comparatively small, foliage density open; season early; chief use home and market. Fruit red: Earliana, Penn State Earliana, Morse Earliana 498, Avon Early, Earliosa, Abel, First Early. Fruit pink: June Pink.
2. *Valiant.* Plants and fruits similar to Bonny Best group but the vines are slightly smaller, not as heavy yielding, and the fruit matures slightly earlier, red, chief use early market garden: Nystate, Crackproof, Early Market, Scarlet Dawn, Redcap, Ventura, Valiant.
3. *Bonny Best.* Fruit $4\frac{1}{2}$–$5\frac{1}{2}$ ounces, deep oblate, corky ring conspicuous, stylar scar a mere dot, cells 6–7, cell arrangement regular; radial cracks common, circular cracks rare; plant semi-erect, spreading, medium size, foliage density slight; second early; chief use home and market garden and canning, red: Bonny Best, Earliest and Best, Chalk Early Jewel, John Baer, Geneva John Baer, Cobourg, Clark Early, Stokesdale, Landreth, Early Canner, Lakeland, Early Garden State.

4. *Globe*. Fruit 6–7 ounces, globular, corky ring negligible, stylar scar small, cells 5–6, cell arrangement regular; plant semi-erect, spreading, large, foliage density medium; midseason; chief use market and canning. Pink: Globe, Gulf State Market, Early Detroit. Red: Manasota.
5. *Marglobe*. Fruit 6–7 ounces, globular, corky ring conspicuous, stylar scar small, cells 6–7, cell arrangement regular; plant semi-erect, foliage dense; midseason; chief use market and canning. Red: Jefferson, Queens, Manahill, Marglobe, Marglobe Supreme, Wisconsin 55, Early Rutgers, Rutgers, Break O' Day, Grothen Globe, Longred, Fortune. Pink: Glovel, Marhio, Judy Pink.
6. *Stone*. Fruit 6–7½ ounces, flattened to deep flattened, corky ring conspicuous, stylar scar medium to large, cells 7–9, cell arrangement irregular; plant semi-erect to erect, medium large to very large, foliage dense; late midseason to late; chief use canning. Red: Stone, Greater Baltimore, Indiana Baltimore, Norton, Santa Clara Canner, Garden State, Scarlet Canner, Simi, Cardinal, Red Rock. Pink: Pepper.
7. *Ponderosa*. Fruit 9–16 ounces, one type rather flat but fairly deep and often oval in transverse section or second type heart shaped, rough, scar broad, cells numerous, irregular, and well filled with pulp but with few seeds; flavor notably mild; plants very large, open, and spreading; late; chief use for slicing raw. Red: Beefsteak. Pink: Ponderosa, Oxheart, Brimmer. Yellow: Golden Ponderosa. White: Snowball.
8. *Comet or Best of All*. Fruit rather small, flattened, smooth, few celled, firm, well colored, uniform; adapted for greenhouse and for trellis culture outdoors: Comet (Minute Man), Grand Rapids Forcing, Best of All, Earliest of All, Signet.
9. *Potato-leaved*. Characterized by strong vines and large, heavy, entire-margined, potato-like leaves. Red: Way-A-Head, Italian Potato Leaf, Red Jacket. Pink: McMullin.
10. *Stemless*. The fruit lacks an abscission layer, and when it is picked the stem and calyx remain on the plant instead of parting from the vine and being attached to the fruit as in most varieties. Instead of clusters of fruit the stemless kinds bear fruits at short intervals on secondary branches. Red: Pennred. Orange: Pennorange.
11. *Hybrid*.
    - (*a*) Inbred lines are crossed.
        - (i) Indeterminate: Fordhook Hybrid, Burpee Hybrid, Clinton Hybrid, Minnesota Hybrid E (Faribault Hybrid), Cornell Hybrid, Spartan Hybrid, Northern Hybrid, Early Delicious, Early Prolific, Breeders Hybrid, Cornelicross.
        - (ii) Determinate: Monarch, Bountiful.
    - (*b*) F_2 segregates (sold as F_2 hybrids): Seed from the hybrid or F_1 generation is saved. This seed, when sown, produces the F_2 or segregating second generation: Stokescrosses 1, 2, 3, 4, and 5.
12. *Golden Queen*. Fruit glossy medium green while young, becoming bright golden yellow when ripe, sometimes faintly blushed with red;

medium to large; medium to late; yellow: Golden Queen, Golden Dawn, Golden Globe.

13. *Tangerine or Jubilee.* Characterized by tangerine-orange-colored flesh and orange-colored fruit: Tangerine, Jubilee, Sunray.
14. *White Apple.* Fruit small and late; fruit color not attractive as it varies from a pale waxy yellow to a faded yellow over the blossom and to a light yellow at the stem end; flavor mild, insipid, very low in acidity: White Apple, White Queen, White Beauty.
15. *Interspecific group.* Such species as *Lycopersicon chilense*, *L. hirsutum*, *L. peruvianum*, and *L. pimpinellifolium* are resistant to certain diseases, and by crossing with the cultivated type (*L. esculentum*) improved varieties are being developed: Vetomold, Pan America, Southland.
16. *San Marzano.* Fruit oblong, 3 inches long, 1¼–1½ ounces; flavor mild, almost tasteless. Thousands of acres are grown in California of which about half is used for making paste and half for canning whole as salad tomatoes; red: San Marzano, King Humber, Jan Ru, Italian Red Plum or Canner.
17. *Small-fruited.* Mostly 2 celled.
    (*a*) *Currant.* Fruit red, somewhat larger than a large currant, borne in numerous, long 2-ranked clusters; skin tough, not inclined to crack; about 350 fruits per pound.
    (*b*) *Peach.* Red, pink, and yellow forms; fruits globular, 1¾ inches, weight about 2 ounces; skin covered with fine hair, soft in texture, suggestive of a peach; cells with thin partition walls, puffy, and only partially filled with pulp and seeds; late.
    (*c*) *Cherry.* Red and yellow forms; fruit small (⅞-inch diameter and weight about ⅓ ounce), globular; midseason; sometimes called "Sugar."
    (*d*) *Pear* ("Fig"). Fruit pear shaped (2 × 1 inches, and weight about ⅝ ounce), walls fairly thick; midseason.
    (*e*) *Plum.* Red and yellow forms; fruit narrow egg shaped, borne on long fruiting stems that are sometimes forked, 7–9 fruits in a cluster, 2 inches long, 1½ inches thick, and weight about 1 ounce, thick outer and inner walls; midseason.

B. *Indeterminate* (*dwarf or tree*). Fruit 4 ounces, flattened-globe shape, broad shallow cavity, scarred at blossom end; plant upright with short, thick, stiff stems, internodes much shorter than in standard varieties, plants never spreading, commonly about 2 feet tall and dwarf tree-like in appearance; leaves thick, much curled, dark green; normally 3 leaves between each flowering truss; late; yielding less than standard varieties. Red: Dwarf Stone. Pink: Dwarf Champion.

C. *Determinate or self-topping* (*bush*). Usually less than 3 leaves between the flowering trusses; generally 2 leaves, sometimes 1, and occasionally no leaves at all between one flower truss and the next; stem eventually terminates in a blossom cluster, thus giving "self-topping" or "self-pruning" habit of growth.

(*a*) Red.

(i) Earliest: Farthest North, Window Box, Tiny Tim.

(ii) Very early: Redskin, Polar Circle, New Alaska, Marman, Dixville.

(iii) Early: Early Chatham, Sioux, Bounty, Firesteel, Red Cloud, Gem, Pennheart, Early Wonder.

(iv) Midseason: Pearl Harbor, Pritchard (Scarlet Topper).

(v) Late: Improved Pearson, J. Moran.

(*b*) Pink: Cooper Special, Fargo (Rosebush).

(*c*) Yellow: Golden Bison, Morden, Mingold.

(*d*) Orange: Orange Chatham, Orange King.

D. *Determinate or self-topping (dwarf)*. Plant upright (about 15 inches); stems stout, without side shoots; leaves thick, dark green. Red: NDAC 303. Yellow: Plains Tree.

Earliana is an early market-garden variety suited to most regions. *Valiant* is smoother in fruit. *Bonny Best* and *John Baer* are widely grown as second-early, home- and market-garden varieties and are canned. *Stokesdale* is widely grown for all purposes but is somewhat light in color for canning.

Gulf State Market (pink) is grown mainly in the Gulf States for shipping. *Globe* (pink) is grown mainly in the South for shipping, but near Cleveland and Detroit for the nearby market.

Marglobe is grown for home and market garden, canning, and shipping, particularly in the East and South. *Rutgers* is a leading canning tomato in the East and Midwest; it is also the dominant variety in the Lower Rio Grande Valley. *Jefferson* and *Queens* are promising for the early Rutgers market. *Longred* has found favor in New York State. *Baltimore* and *Stone* are chiefly canning varieties east of the Rockies. *Improved Pearson* and *Santa Clara Canner* are leaders in California.

Southland, besides resistance to collar rot and fusarium wilt, shows a moderate degree of resistance to early blight and to one form of late blight; it is adapted to the South.

Plant Characteristics *

Root

Owing to the usual transplanting procedure, the primary root is damaged, and a dense system of lateral roots is formed. These

* Descriptions have been given[449] for 49 tomato characters with named genes, and more than 60 other tomato characters without identified genes have been listed. Thirty-one of the named genes have been located on a chromosome map.

develop rapidly and, in mature plants, may spread several feet. Most of the root system occupies the first 8–10 inches of soil, but occasional roots may penetrate quite deeply.

Pigmentation of Fruit

Three flesh colors occur in the tomato, namely, red (lycopene pigment), yellow (yellow carotenoid pigments), and tangerine (prolycopene pigment). Genetically, red is usually classified as *R*, the small *r* representing nonred or yellow. *T* is classified as nontangerine and *t* is tangerine. These two pairs of alleles give four colors genetically designated as red (*RRTT*), yellow (*rrTT*), dark tangerine or orange (*RRtt*), and light orange (*rrtt*). Skin color increases the number of possible colors present to eight. The skin, peel, or epidermis is either pigmented yellow (*Y*) or nonpigmented (*y*).

When the genes for flesh and skin color are combined the eight colors present are as follows: *RRTTYY* (red); *RRTTyy* (pink to purplish, i.e., red flesh under colorless peel); *rrTTYY* (golden yellow); *rrTTyy* (lemon yellow to white); *RRttYY* (very dark tangerine); *RRttyy* (dark tangerine); *rrttYY* (light tangerine); *rrttyy* (very light tangerine).

Nearly all commercially important tomato varieties are red-fleshed. The intensity of color in this type depends upon the balance between the red and yellow pigments. The environmental conditions of the tomato will affect this balance. For example, a tomato will not develop yellow or red pigments at temperatures below 50°F. Between 50°F. and 86°F. both red and yellow pigments develop. Above 86°F. the production of lycopene (red) is suppressed, but if a temperature lower than 86°F. is restored the red color will again develop. However, if the temperature in the interior of the tomato rises over 104°F., the mechanism for producing lycopene is destroyed and no further red color will develop. This happens occasionally in field tomatoes and produces unsightly yellow "shoulders."

Producing Tomatoes

Climate

The tomato is sensitive to cold and should not be planted until danger of frost is past. It requires 80–120 days from seed

to bearing, according to type, but about a third of this period can be spent under glass. Low temperatures when the flower clusters are small is a cause of rough fruit.

Tomatoes produce best with average monthly temperatures of 70–75°F., but are grown commercially at as low as 65–70°F. and as high as 75–80°F. The crop is poorly adapted to average monthly temperatures above 80°F., and fruit is damaged at near 30°F. Tomatoes are subject to chilling injury at or near 40°F. Such fruits do not show any indication of injury at the time of picking but are frequently responsible for losses at terminal markets because of erratic ripening and rots.

Fruit setting may not occur if the flowers open for pollination when the temperatures are too high or too low. Night temperatures below 59°F. for several hours or day temperatures above 100°F. may cause barrenness. The best red color develops with average daily fruit temperatures of 65–75°F., and yellowness increases as temperatures go above 80–85°F. This effect depends on how high the temperature goes and how long it stays up. Seed germination is best in a soil near 65–75°F., slows down at 50°F., and decreases very rapidly at lower soil temperatures.[241]

Infrared protectors [155] are useful in some cases against frost hazard down to 26°F.

Hormone spraying is helpful in producing early tomatoes (which may tend to be seedless) in areas where fruit setting is delayed by cold nights. Such localities include those adjacent to large bodies of water, muck land, mountainous areas, most northern areas, or any area with prevailing night temperatures of less than 59°F. during flowering of the first clusters. The spray is applied to the first, second, and third flower clusters as a fine conical mist. If most of the material is applied to the leaves instead of the blossoms stunting of the vines may occur. The effect of growth-substance treatment is to shift the yield of fruit to an earlier period in the season rather than to increase the yielding capacity of the plants.[255]

Water sprays of *para*-chlorophenoxyacetic acid, 25 ppm., applied to the first (crown) flower cluster of field tomatoes may result in more and larger early fruit.[434] This material may cause distortion and other injury of the foliage, so that the yield for the whole season is reduced. *Alpha-ortho*-chlorophenoxypropionic acid (CIPP), 1/7 ounce per 50 gallons of water (25

ppm.), 150 gallons per acre, can be applied to advantage, without injury to the foliage in three, weekly, early applications.

In western Washington,[276] five varieties were grown in the field. One series of plots received blossom sprays of *para*-chlorophenoxyacetic acid, another was pruned to 2 branches per plant, a third was pruned to 3 branches per plant, and a fourth was left unsprayed and unpruned as a check. Fruit size and yield were increased by spraying the blossom clusters 6 times at weekly intervals beginning June 25 with 30 ppm. *para*-chlorophenoxyacetic acid. Pruning had little effect on yield or fruit size.

In the South, immature tomato blossoms drop rapidly during extreme heat and dry air owing to increased transpiration. Because of slow pollen-tube growth, the blossoms may die if the weather is unfavorable after pollination has occurred. Blossom drop results in a low yield because of the scanty set of fruits and the continued growth of vines, often to enormous size. Summer Prolific is a hot-weather variety developed in Texas.

When rows of trees run north and south through a field, tomatoes should be planted in spring along the east side of the trees, where they receive afternoon shade. Possibly the old saying of gardeners that the morning sun is most beneficial for many plants should be restated as: afternoon shade is beneficial.

Soil and Its Preparation

A well-drained, fairly light, fertile loam with a fair moisture-holding capacity is ideal. For very early crops, a sandy loam soil is best.

In Illinois, where blossom drop is often serious, these guides have been given: in dark soils and light-colored soils high in fertility, plant second-early varieties; in light-colored soils low in fertility, plant only the larger-vined, later varieties. When fertility is low, the late types are preferable in southern and probably in central Illinois. In northern Illinois, second-early types with a fairly large vine are being grown.

A well-prepared soil is essential for success. In a dry spring it is difficult to secure a good stand even on a mellow soil, but if the soil is cloddy plant setting is an almost hopeless task.

Tomatoes do best in a soil that tests *p*H 6.0–7.0. When acid soils are limed, the calcium and magnesium supply is increased, toxic aluminum, manganese, and iron are made insoluble, phos-

phorus and nitrogen are increased, and the soil structure is improved. (See also Manure and Fertilizer.)

The tomato crop should not succeed itself on the same ground, and it should not follow potatoes, because of disease factors.

DRAINAGE. Poorly drained soils carry an unfavorable soil flora for plant growth and interfere with the absorption of nutrients. Also, a reducing condition is developed, which is the opposite of the oxidizing condition favorable for maximum yield. Associated with drainage is the leaching of bases, which produces acid soils.

Sources of Plants

Plant production in northern regions is usually limited to plants grown by truck and market gardeners for their own needs, though they, as well as greenhouse operators, often raise some for local demand by such as home gardeners. Canners' growers commonly receive plants from the factory, and these often are southern grown.

The growing of plants in the South, especially in Georgia, Florida, Mississippi, and Texas, for shipment north has become a large industry. In southern Georgia seeding usually begins about February 20 and continues until about April 1. The seeds are drilled 4, 5, or 6 rows abreast in wide beds 14–16 inches apart, 3–5 pounds per acre. As soon as the young seedlings show the first set of true leaves, applications of a fungicide are begun and are continued at 10-day intervals until the seedlings are pulled. When the plants are 6–9 inches high, they are pulled by hand and tied in bundles. These bundles are put into burlap bags and hauled to the packing house. There the bundles are opened, sorted, and reassembled into bunches. The bunches are then rolled in wet peat moss, wrapped in paper, and tied. They are shipped in hampers or crates.

If for any reason, such as unfavorable soil and weather conditions, immediate transplanting is unwise, the following procedure of plant handling is advised.[267]

1. Remove lids from all the baskets.

2. Do not open any bundles until immediately before transplanting. The roots of the plants in the bundle have probably established a water-absorbing connection with the packing material. If this connection is broken the watering recommended later will be less effective.

3. Provide extra baskets, approximately one-fourth the number of baskets of plants to be handled.

4. Remove from each basket: 1 bundle if each contains 100 plants; 2 bundles if each contains 50 plants. Place these removed bundles in the extra baskets. Bundles removed from the baskets should be taken from the middle of the basket.

5. Readjust bundles in the baskets so as to permit free ventilation of all the bundles.

6. Tear a hole in the bottom of the paper wrapper around each bundle. This hole will permit the rapid absorption of water during the dipping and permit immediate drainage after the removal from the water.

7. Place baskets in 3 inches (not over) of water for 5 minutes. Do not wet the top of plants. The plants themselves will absorb little water during the 5-minute wetting period. But the packing material in each bundle should become saturated, thereby providing a reservoir of water for gradual plant use. Watering of the plants should not continue beyond 5 minutes.

8. Watered baskets should not be stacked.

9. Desirable storage temperature for baskets of plants is 50–60°F. If a cellar is used for storage, it should be well ventilated. Storage in an outdoor shed is satisfactory if plants are protected from sunlight and drying winds. Proper storage locations and methods will depend upon prevailing weather conditions.

10. A second watering may be necessary. An examination of the tops of the plants will provide the answer.

11. After the bundles are opened, protect plants from intense sunlight and drying winds. Roots should be kept damp.

Sowing the Seed

About 2 ounces of seed are ample to produce enough plants for an acre. For seedbeds, a 3-12-12 fertilizer applied at the rate of 5 pounds per cubic yard of composted soil may be helpful.

Greenhouse-grown plants. The seed is sown in flats 6–7 weeks before the plants are set in the field. About 70–80°F. is maintained at first. When the second leaf appears, the seedlings are pricked-out into other boxes. Sometimes they are moved again later until, finally, when they are nearly ready for setting out, they are 3–4 inches apart each way. In the final shifting they may, on a small scale, be placed in pots or cans. Overcrowding or lack of sunlight causes spindly plants. Stocky, well-branched plants transplant best and bloom and set fruits first. Earliness of maturity depends more on subsequent rate of growth than on large initial size of seedling.

If plants are to be moved to the field about May 25 or later, there is no increase in early or total yields from seeding earlier

than March 25.[330] Seeding as late as April 8 may give as large or larger yields than earlier seeding, and the plants cost less. Topping at 9 inches keeps the plants from becoming too leggy and produces more compact plants that transplant better. Topped plants will also produce larger early yields if transplant-

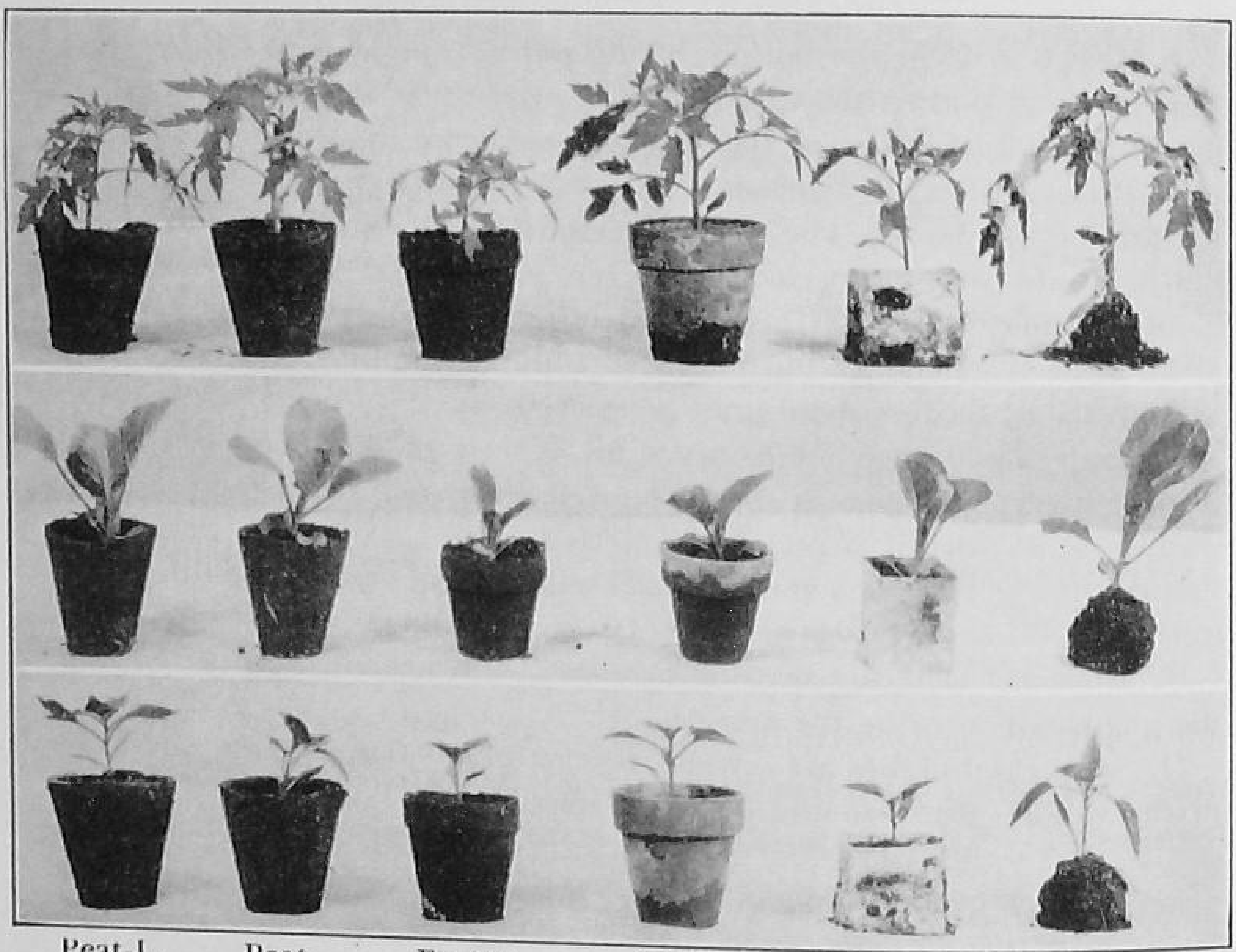

Fig. 62. Plants showing effects of lack of nitrogen when grown in containers such as paper bands or Fertex where cellulose is high and bacteria use nitrogen in decomposing paper. *Top,* tomatoes. *Center,* cabbage. *Bottom,* pepper. (*Courtesy Dr. E. S. Haber, Iowa State College.*)

ing is unduly delayed. Giving the seedlings 25 percent more space (80 plants instead of the usual 108 per flat of 14 × 20 × 2¾ inches) gives a slight increase in early yields when the plants must be held 3 weeks longer in the flats but makes no difference when the plants are set at the normal time. Growing the plants in deeper flats with 33 percent more soil does not affect the yield.

At Cornell University,[66] seed of an Earliana strain was sown at intervals of 7, 11 and 15 weeks before the usual date for field planting. The seedlings were spaced 2 × 2 and 4 × 4 inches in flats with a 2-inch depth of soil. Parts

of the longer leaves of half of the plants were clipped off without removing the growing points; the other half of the plants served as a check. All three treatments were given in the greenhouse. The plants were all set out in the field on the same day. An increase in the early and total yield was produced by the younger plants. Their capacity for quick growth resumption after field setting was a factor associated with large early yields. The wider spacing in the flats prior to field setting also resulted in increases in the early and total yields. Plants spaced 4×4 inches in the flats and moved to the field when 7 weeks old produced over 5 times more early fruit than those of the same age but grown at 2×2 inches. Trimming, although detrimental to the appearance and condition of the plants, did not affect yields significantly.

Plants grown in paper pots may give larger early and larger total yields than those grown in flats, because in the former instance roots are disturbed much less when the plants are set in the field. Plants grown from seed sown directly in pots are as good as those transplanted once or twice.

The type of container for growing tomato plants for transplanting affects the growth of the plant in relation to: [256] the moisture-retaining capacity; the readily decomposable cellulose present; and the volume of soil. Commercial bands which are not treated often produce poorer plants than standard clay pots or tin cans. But plants are more difficult to remove from cans than from pots or bands. Plants grown in clay pots painted black on the outside may make better growth than plants in unpainted pots.

Hotbed-coldframe method. The seed is sown in rows in hotbeds at least 6–7 weeks before field planting. About 2 weeks after seeding the plants are ready for transplanting to coldframes, where they are set 2–4 inches apart each way and where they remain until moved to the field. The usual practice is to cut the plants apart with a spade or trowel, allowing each plant to retain its square of soil. Another plan is to transplant seedlings to flats, instead of to the coldframe directly, and to set these flats in the coldframes, so that at outdoor planting time they can be moved to the field and the plants taken from them there. Sometimes the seeds are sown thinly in the hotbed or coldframe and the plants moved directly to the field without transplanting. The rows should be at least 4 inches apart in the beds.

Direct-seeded coldframe method. In some areas, e.g., California, most of the home-grown plants for the cannery crop are grown by this method. The seed is sown in rows or broadcast thinly in beds where the plants will remain until they are ready to transplant into the field.

Open seedbed. As soon as the ground is warm in the more southern regions such as New Jersey the seed is sown in drills 12–14 inches apart with 5–6 seeds to the inch.

The open seedbed is not adapted to areas with short growing seasons nor to early crops. It is used for the late shipping crop in southern and coastal districts and sometimes for late crops elsewhere with quick-maturing varieties. Beds are prepared in California in a well-drained, sheltered, sandy spot. Narrow beds, 30–36 inches from center to center, are thrown up with a lister; the ridges are harrowed down and levelled. Two rows are sown on each bed, and the furrows between the beds are used for irrigation. The seed is drilled in with a seeder when the soil becomes warm and frost danger is over. With favorable temperature for germination 20–30 seeds are sown per foot. The seedlings are thinned to 12 per foot.[308]

Direct seeding. Direct seeding is feasible in some long-season districts. Such conditions as below freezing temperatures in transit and transportation tie-up causing damaged plants, unfavorable weather and soil conditions at planting time, and unseasonable factors that delay plant growth in the southern seedling beds may be avoided. Temperatures near 55°F. are sufficient for germination under moderate rainfall conditions. Direct-seeded tomatoes begin to produce ripe fruits about 2 weeks later than transplants.

Seeding is done, about 20 ounces of seed per acre, in rows 4–5 feet apart with a gang of 4 hand seeders pulled by a tractor, somewhat before the last killing frost. When the plants are 4–6 inches tall they are thinned by hoeing or cross-cultivation. If more than 1 plant remains at the cross mark, hand thinning is done. This method wastes seed, involves labor in thinning, and cannot be practiced when tomatoes follow a winter crop of other vegetables. But it lessens the cost, the check of plant growth, and the danger of damping-off. In the Imperial Valley most of the crop is seeded in the field and protected with brush and paper shelters until after danger of frosts.

In the lower Rio Grande Valley,[139] the spring crop is sown directly in the field, much like corn. On well-prepared, pre-

irrigated land ½ pound of seed per acre is usually enough where the rows are 6 feet apart. Most growers use twice this quantity of seed and sow pairs of rows which are alternately 6 feet and 3 feet apart. But some growers prefer solid plantings in rows spaced 3½ feet apart, especially for the extra early and weak-vined varieties. The seed is sown in the moist soil in the bottom of the water furrow and is covered with ½–¾ inch of soil;

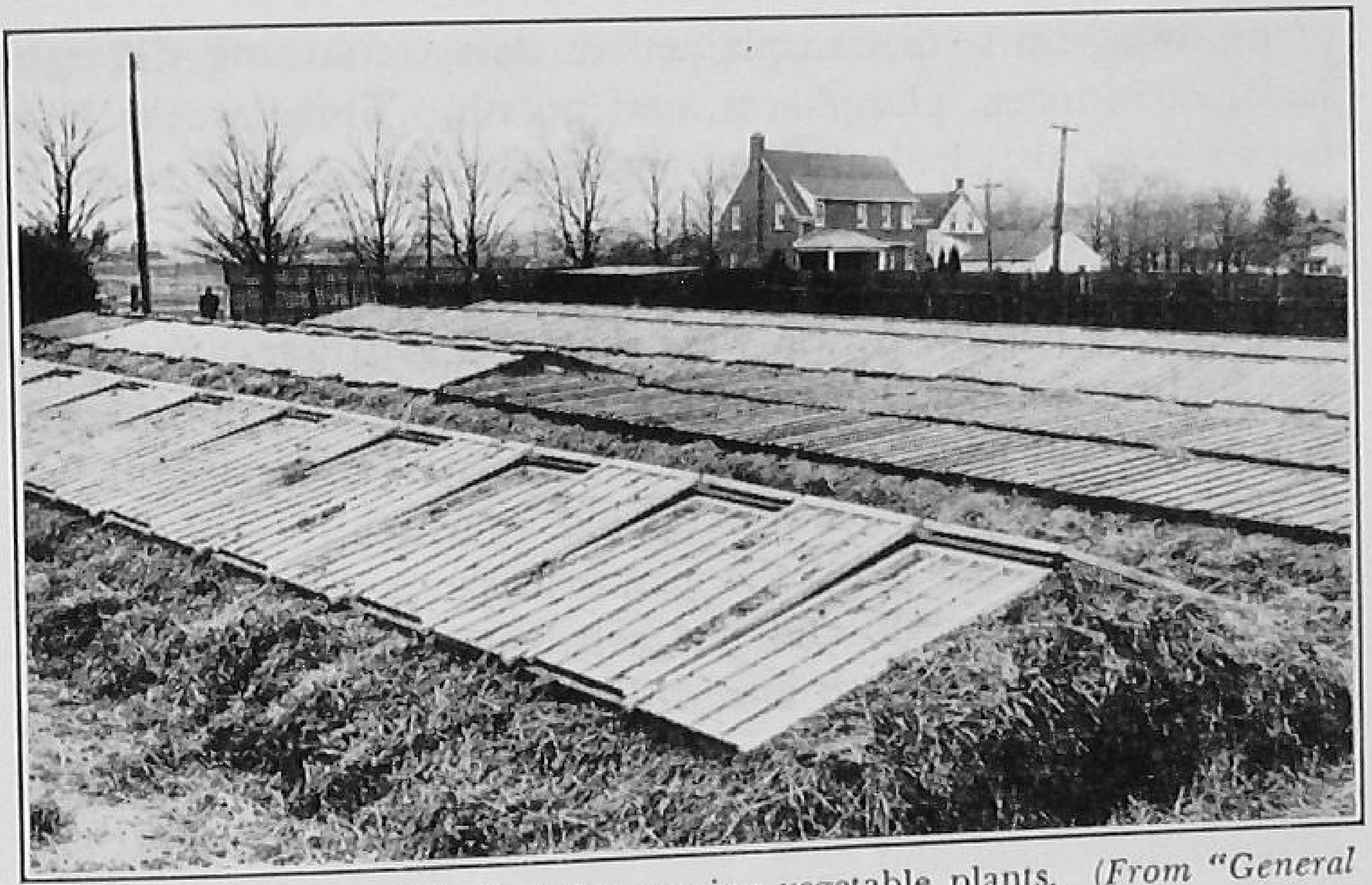

FIG. 63. One type of hotbed for starting vegetable plants. (*From "General Horticulture" by J. S. Shoemaker, J. B. Lippincott Co.*)

the deeper seeding is done on the light sandy soils. Planters equipped with press wheels help in securing good stands. Seeding of the spring crop in this area is started in early December and finished by mid-January. Seeding of the canning crop may extend into mid-February.

Hardening the Seedlings

Shortly before planting in the field, especially in areas with a short growing season, tomato plants commonly are grown at cool temperatures with plenty of ventilation, as in a coldframe. The belief supporting this practice has been that hardened plants can better withstand lower temperatures, wind whipping, and other adverse conditions. (See also Hardening of Cabbage.) But "hardening" of young tomato plants, either through growing at cool temperatures or withholding water, stunts and slows

growth, does not make the plant better able to withstand frost, and results in lower early yields of fruit. Over-hardening, either by cold or by keeping plants dry, promotes rough fruit. It does its harm when the blossom cluster is tiny, and so the rough fruits are on the early clusters. Tomatoes should not be set outdoors until danger of frost is past.

In New York,[331] tomato plants were grown in the greenhouse and coldframe, using a greenhouse composted soil. Seedlings of uniform size were transplanted to flats containing different ratios of nitrogen, phosphorus, and potash. Three weeks later the seedlings that had nitrogen and phosphorus but not potash were the largest, were very dark green, and had made a soft, succulent growth. Those that had received a mixed fertilizer containing 6 percent potash were shorter and stiffer. Seedlings that had received the same amount of nitrogen and phosphorus plus 12 percent potash grew stockier, had stiffer stems, and had olive-green foliage. When 8 weeks old, at which time they were transplanted to the field, the plants without potash were 16 inches tall, dark green, and had soft, succulent stems. Those receiving 6 percent potash were 16½ inches tall, medium green, with firm stems with some purple coloring in the stems. The plants receiving 12 percent potash were 1 inch shorter with olive-green foliage and stiff, firm stems. Plant growers rated this lot as the most desirable type for transplanting to the field. The plants that received the high potash fertilizer required fewer replants and produced more early tomatoes.

Sucrose foliage sprays (10 percent with a small quantity of detergent as a spreader) applied 3 times at 1-day intervals before pulling the plants may markedly reduce post-planting shock and mortality when nonhardened or partially hardened plants are set under high temperatures or when stored for 3 days in the dark at 68°F. before planting.[363] Some growers believe that spraying with Bordeaux hardens the transplants.

Soil application of certain chemicals plus reduced temperature and soil-moisture levels has shown promise in "hardening" greenhouse-grown tomato plants. E. N. Learner and S. H. Wittwer, Michigan State College, found differences in root development, stem thickening, growth rates, fresh and dry weights, total reducible sugar contents, transpiration rates, dates of anthesis, fruit quality, and total yield in tests that included *alpha-ortho*-chloro-

phenoxypropionic acid, maleic hydrazide, *beta*-methylumbelliferone, and 4-phthalimide-2,6-dimethylpyrimidine (abstract of paper presented before American Society of Horticultural Science, 1951).

Methods of Field Setting

Hand setting. Potted or blocked plants are set by hand. Many growers like to have the first cluster of bloom set before planting. Some even prefer to have the second cluster set as well and perhaps the third showing bud. Small seedlings are often set with a regular dibber, or with one made from a shovel handle sharpened at one end. Larger seedlings are set in a furrow or with a trowel. All sizes of plants must be set well down in the soil. A tall, slender plant may be snapped off by wind. Such plants may have provided for them longer holes than usual, and they may be spaced on their side with only part of the stem aboveground, the stems being covered with 4–5 inches of soil. The plants will straighten in a few days. Extra stem surface underground may promote an extra amount of root system.

Mechanical setters. Mechanical setters are economical for a large acreage. The rows should be long to avoid frequent turning. The field must be fairly level, well prepared, and free from clods and trash. As the shoe of the setter will not go deeper than the plow sole, deep plowing is essential. The machine waters the plants and thereby helps them to survive. It is limited to use with one type of plant, namely, the seedling with practically no soil on the roots.

Use of Water and Nutrient Solutions in Transplanting

Watering is usually beneficial at planting time. But even plants that are watered may make little headway for several weeks after setting. The growth may be speeded by adding nutrients to the water.

One "starter" or transplanting solution is a 15-30-14 combination of chemically pure ingredients which dissolve completely in water, thus avoiding the need to strain out the insoluble residue as is necessary with ordinary fertilizers. Good results may be obtained from the 15-30-14 formula at the rate of 4 pounds in 50 gallons of water, or from 10 pounds of a 5-10-5 in 50 gallons, applied at transplanting time at the rate of ¼ pint

per plant. Increased yields of 1–1½ tons per acre are not uncommon from the use of these solutions. The beneficial effects are especially marked at the first picking of cannery tomatoes. Market gardeners are not likely to find the practice so beneficial because of the more intensive fertilization of their land and the better nourished plants they usually employ.

Treatment of the roots of transplants with 10 ppm. solutions of indolebutyric acid (hormone) and vitamin B_1 does not increase yields.[309]

Conditions for Setting

Plants should not be set when the ground is either too wet or too dry. "Mudding in" the plants may seem to be desirable as no watering is necessary and the survival is high. But the soil is badly puddled around the roots and the plant may be retarded as the roots find it difficult to grow in a hard ball of packed soil that is too close to the plant to be broken up with the cultivator. If setting in hot, dry, or windy weather is necessary, the work should be done in the cool of the day, either early morning or late afternoon. If the wilting is delayed 12 hours, the plant will usually survive.

Replacing dead plants is often neglected by the grower, who thereby may sacrifice part of the yield. If 5–10 percent of the plants are missing, plants should be reset as soon as possible. Since water for such plants must be carried by hand, a favorable time, such as a cloudy day, is chosen for resetting. If the losses from machine planting are 40 percent or more it may be best to disc the field and replant.

Spacing

Plants commonly are set 4×4, 3×5, or $2\frac{1}{2} \times 6$ feet apart. They are often set $2 \times 3\frac{1}{2}$ feet apart (7 square feet per plant); this may give a higher early and total yield but somewhat smaller fruit. If set too far apart, the plants do not protect each other and are excessively exposed to the weather, so that yield may suffer.

Seasonal changes in temperature and rain affect vine growth and influence the optimum spacing. When rain is well distributed, early varieties with normally restricted vines may make a vigorous growth and need more space than usual. In a dry

year when nitrogen may accumulate in the soil, the earlier types may develop abnormally small vines and the late varieties very large ones. In California, late varieties which make vigorous vine growth are set 6 × 6 or 6 × 8 feet apart.

On large areas, driveways at convenient distances, say every eighth to tenth row, make it easier to load the fruit.

Manure and Fertilizer

A liberal application of well-rotted manure when the soil is being prepared is desirable. In tomato growing there possibly is some physical effect from manure separate from the organic matter and nutrients supplied. Fresh manure, especially if strawy, should not be used under the plants. Green-manure crops, when plowed under, help to improve the condition of the soil.

On many acid soils lime does not increase the yield of tomatoes. But if lime is applied in conjunction with increased amounts of potash, larger yields may result. The influence of residual manure is comparable to that of potash. The benefit arising from the residual manure may be related to its ability to keep potassium from being fixed by preventing fluctuations in the soil moisture. Possibly the tomato may be classed as a plant requiring a relatively greater potassium supply than spinach or than other plants that have a low calcium content.[62]

It is efficient to apply mixed fertilizer around the plant by hand and cover with a cultivator. Sowing fertilizer in strips is less laborious. Because of the wide spaces between plants the roots may not be able to reach much of broadcast fertilizer until late in the season. The plow-sole method is useful on the heavier soils. Applying fertilizers through the sprinkling system is feasible in some cases, at least for supplementary purposes.

The amount to apply depends on such factors as method of application, spacing of plants, and composition of the fertilizer. Heavy applications close to the plant are sometimes worse than none at all. Fertilizer salts are extremely toxic if they touch the roots. Since high-analysis fertilizers are the most soluble, great care should be taken in applying them.

In general, a lack of nitrogen causes lighter-green leaves than are typical; a marked shortage of phosphorus or potassium often results in a darker green than usual. There is more phosphorus

in the fleshy part of a tomato fruit than in the seed. Phosphorus is as essential for the production of the nonseed portion as for the seed portion of a tomato.

About 100 pounds of nitrogen is needed per acre for a good crop; 3,000 plants carry less than 1 pound of nitrogen at transplanting time.[179] Thus between transplanting and harvest about 100 pounds of nitrogen must be absorbed by 3,000 plants. Only 3–4 pounds of nitrogen are used by the crop in the first month after transplanting, but 20–25 pounds are used in the second month, and 30–40 pounds in the third. Therefore, much of the nitrogen is absorbed in the second and third months and must be available then for maximum yield. Ten tons of manure may carry 80 pounds of nitrogen, about 40 percent or 30 pounds of which is available in 1 year. Some 2–5 percent of the nitrogen in organic matter generally occurring in soils is available within a year, and perhaps another 30 pounds are added to that from manure. Plowing under a cover crop may supply another 30–40 pounds. Some is lost by leaching. The problem often is not only how much nitrogen to apply but also when to apply it.

An acre of tomatoes requires more available nutrients than a grain crop;[237] furthermore the tomato plant blooms for 3 months, whereas the grains pollinate in 1–2 weeks. These latter crops may drain nutrients out of the remainder of the plant to mature the fruit without greatly influencing the crop. In the tomato this drain affects the later set of fruits. In many cases a side-dressing of fertilizer at the time of the last cultivation helps to avoid fall starvation and to encourage ripening.

The crop responds to copper sulfate on acid muck and to manganese sulfate on alkaline muck. Phosphorus and potash are usually especially beneficial on muck.

Application of skim milk and commercial fertilizer to tomato plants, either singly or in combination, may give increases in No. 1 ripe and total ripe Bonny Best tomatoes.[194] The skim milk is applied at weekly intervals for the first 5 weeks after transplanting in increasing amounts beginning with 10 cubic centimeters per plant the first week and ending with 50 cubic centimeters the last week. Soil applications of milk products may result in some changes in the chemical composition of the soil and an increase in biological activity.

Acid and Total Solids Content

The acidity of ripe tomatoes is an important factor, as is the total solids content, in processing. Acidity can affect the product in many ways. For many products, a moderately high acidity is desirable. But for tomato paste, tomatoes that are rather low in acid are desirable because this is a concentrated product in which the acidity is accentuated. In juice, any variation in the acidity will cause changes in flavor. Manufacturers of cream of tomato soup have had trouble with curdling of the product during some parts of the season. Curdling could be caused by excessive acidity in the tomatoes.

Sixteen varieties of tomatoes tested in New York [227] contained higher total acid on the fresh or dry-weight basis and higher total solids when grown under restricted soil moisture than when grown with abundant soil moisture. The total acid content of tomato fruits often is high at the beginning of the season, declines as the season progresses, and rises at the end of the ripening period. This general trend can be altered by changing soil moisture conditions. The final upward trend may not be observed when the season ends abruptly. In some varieties these variations are not so marked as in others. Field tomatoes may vary as much as 25 percent in total acid during the year. Variations in acid content of varieties occur from year to year.

The total solids content of tomatoes also differs among varieties and is modified by growing conditions. The effective use of fertilizers, especially potash, increases the total solids. Potash tends to produce tomatoes that are higher in total acid, especially when relatively large amounts of it are added to the soil. Nitrogen fertilizer seems to have little effect on the acidity of the fruit.

Pruning and Staking

In the indeterminate type, the plant, when tied to stakes or wires, forms an erect stem. The side shoots in the branch angles are removed. Staking is the general practice in Mississippi, Tennessee, Louisiana, east Texas, the Marietta district in Ohio, parts of Indiana, California, Oregon, Massachusetts, the Palmetto and Manatee section of Florida, and parts of Canada.

Advantages of staking are: keeping the fruit off the ground (less decay); more early fruit; easier harvesting; cleaner, firmer,

and possibly larger fruits. Chief drawbacks are: greater labor and cost, more blossom-end rot, more cracking of fruit, and a lower total yield. In certain regions it is unwise to remove any foliage because exposure of the fruits to the sun may keep them from developing a bright color, and sunscald occurs in hot weather. Some fruits on the first-formed or lowest clusters are often rough, ridged, or ill-shaped and are unsuitable for slicing because of the wastage in preparing for use. Likewise, tomatoes produced on the top clusters often are small and lack firmness.

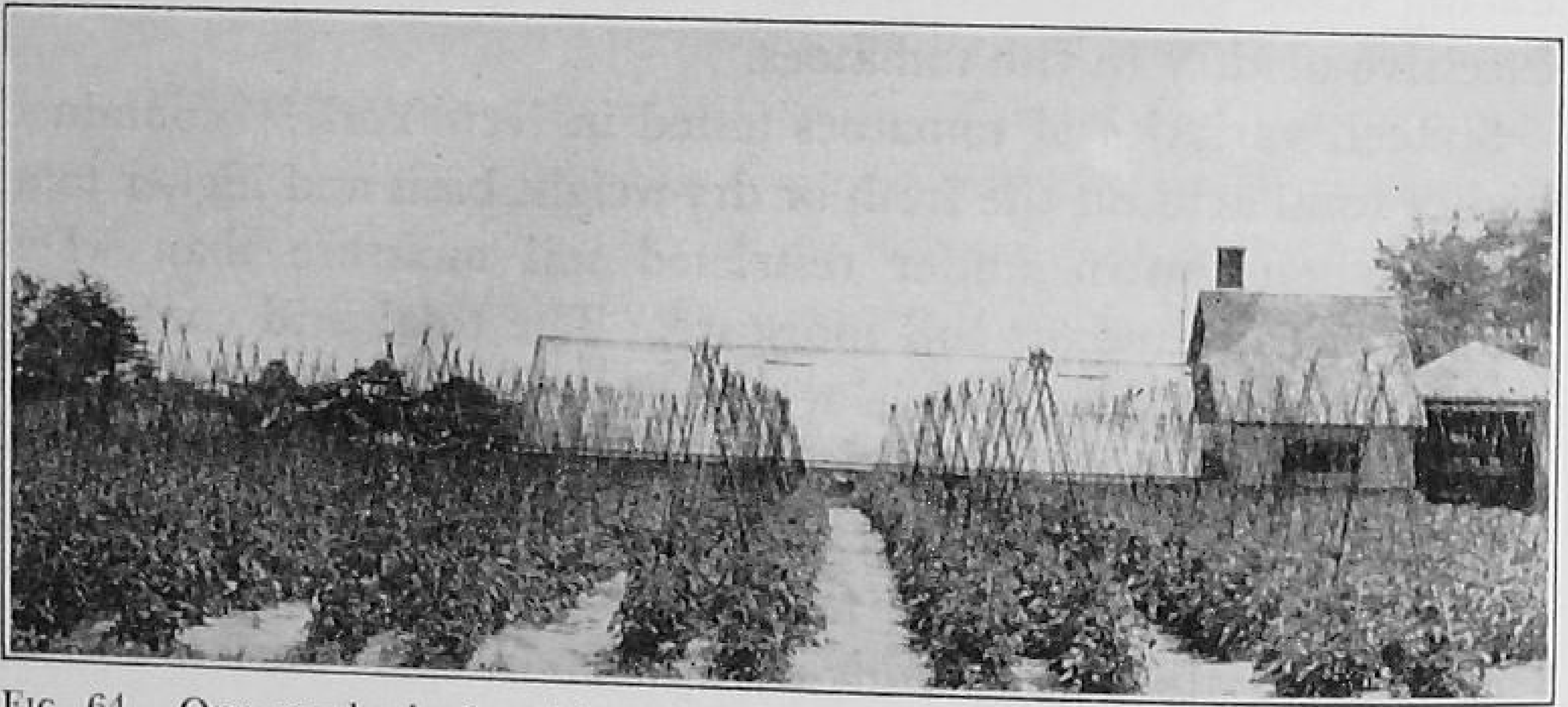

FIG. 64. One method of staking tomatoes. (*Courtesy O. J. Robb, Horticultural Experiment Station, Vineland, Ont.*)

Tomatoes in the top clusters are often sunburned, or they show subnormal color when ripe because of the depletion of foliage and weakened vitality of the vine late in the season.

Stakes are driven for each plant, or strong posts are set and wires are stretched tightly along the rows. The plants are tied up as soon as set out, but attached loosely to allow for growth. As they increase in height, more ties are made. A soft but strong tying material is used.

In Massachusetts,[449] strong end posts, such as 4 × 4 inch, are set. These are anchored with a guy wire or stake 4–5 feet beyond the posts. The supporting posts are placed 15–25 feet apart along the row. These can be of 1-inch or larger pipe, 2 × 4's or 3 × 4's. The top wire (No. 9 or 10) is then strung tightly on the posts. A smaller wire (No. 18 or 19) along the bottom on which to tie the strings completes the trellis. The rows are spaced 4 feet apart. The plants are spaced 1 foot for single-stem training and 22 inches for 2 stems per plant. Single-

stem plants set 10,000 to the acre produce more early fruit than 2-stem plants set 6,200 to the acre. All suckers are removed as soon as they appear, and the stems are twisted around the strings.

In the A-shaped trellis two 2 × 3's about 4 feet long are bolted together at one end, and the other ends are spread, each one standing in a row of plants and set at intervals of about 12 feet. Wires are stretched across these frames about 10 inches apart and 2–3 stems per plant tied to each. End posts must be securely braced.

Still another plan is to set plants about 2 feet apart in rows 3–4 feet apart and to prune to a single stem per plant which is then tied to a stake or stout wire. All side branches are removed as soon as formed. Sometimes a grower may better protect the fruit from sunburn and increase the yield by leaving 2 main stems per plant. After 3–4 flower clusters have set fruit, the plant is cut off just below the next cluster of flowers that appears, above the clusters being retained. This topping permits the plant to direct its energies to the development of the fruits already begun.

Still another trellis method is to plant in double rows 1½ feet apart with the pairs of rows 3 feet apart. The rows run north and south for maximum shading. The plants are set 20 inches apart in the rows and are staggered in the double rows. Steel fence posts are driven about 50 feet apart in the middle of the 1½ foot spaces, and a wire is stretched from post to post, 3 feet from the ground. A plaster lath is driven 3–4 inches into the ground on the north side of each plant and tied to the wire. The rows should be short with this type of trellis, as it is impossible to walk across the field.

In small plantings a hoop trellis will keep the fruits off the ground, reduce anthracnose infection, and give more usable fruits.[432] Number 9 gage galvanized wire is used. The hoops (lower hoop, 16 inches in diameter; middle hoop, 18 inches; top hoop, 26 inches) are held in place horizontally by welding them to four vertical wires. The uprights extend 8–9 inches in the ground below the lower wire so the trellis will not tip over. They are then turned outward at an angle sufficient to hold the second and third hoops in place 8 inches and 16 inches, respectively, above the first.

Some growers in the northeastern states "leaf prune" to stimulate the early formation of the branches and the setting of more fruit clusters. All the leaf except the inner 2 lobes or segments is cut away when the plants are 6–9 inches high. After the branches have started no further pruning is done and the plants are left to grow and spread on the ground.

In Missouri,[175] by allowing cut back side shoots to carry extra leaves, an increased set resulted and yields were improved. Cracking and sunscald may also be reduced. The side-shoot leaves immediately below the cluster seem to account for most of the increase in yield. One side shoot below each fruit cluster gave nearly as high an increase in yield as did two.

Cultivation

There is a tendency to overdo cultivation in the belief that in some manner the crop receives benefit. Cultivation is essentially a weed-killing operation, and maintenance of a soil mulch is of secondary importance. But certain soils need aeration, and some cultivation must be done even in the absence of weeds.

Mulching

Occasionally, tomatoes are mulched with straw when the plants are 12–15 inches high. Mulching saves cultivation, keeps the vines and fruit from touching the soil, and reduces the amount of spoiled fruit. It helps conserve moisture and may lessen the amount of blossom-end rot. To keep the leaves of mulched plants from turning yellowish, application of nitrogen fertilizer may be needed.

In Massachusetts,[185] the water, total solids, total sugars, and ascorbic acid contents of tomatoes are similar for check and mulched plots. Mulching seems to increase the mineral content, especially of phosphorus and potassium.

Irrigation

In the lower Rio Grande Valley, since spring tomatoes are started and grown during the driest part of the year, they are planted on irrigated land.[139] Irrigation before planting is very important, and supplemental irrigation is needed during the fruit setting and fruit maturation periods. To facilitate watering, after the vines cover the soil, cultivation is done to work

soil to the crowns and leave well-defined water furrows between the rows. Strong drying winds often occur from about March 1 until the harvest is well advanced. Rain is usually light during this critical period. Watering during March and early April is important, but water applied during the harvesting season is even more so, especially on light sandy soils. Many growers irrigate after each picking, but this will not work on flat, heavy land.

The objectives of a study in Washington[275] were to make a comparison of sprinkler and furrow irrigation, and to determine desirable amounts and frequencies of water application for a selected soil type. The sprinkler system consisted of lightweight, portable pipe fitted together with quick couplers and slowly revolving sprinklers. The results tended to show that:

1. Intervals between irrigations have little effect on yield of tomatoes in Spokane Valley, as long as adequate water is applied during the growing season. Gardeners commonly irrigate at about 8-day intervals, and no evidence was found that would suggest a change from such a schedule.

2. Tomato yields were considerably affected by varying the amounts of water applied. Eleven inches of water, applied per season, compared with 20 inches, (*a*) increased the number of ripe fruits, (*b*) increased the total weight of fruit harvested per plant, and (*c*) reduced fruit cracking. The individual fruits were larger on plots receiving the greater water applications compared with fruits from plots receiving 11 inches of water per season, but the lesser number of fruits per plant was responsible for the lower yield per acre.

3. Cracking tendencies in tomatoes were as serious in the furrow-irrigated plots as in the sprinkled plots. Cracking was greater with the 15- and 20-inch water applications than with the 11-inch application.

4. The date of maturity could be altered slightly by total water applied. Tomatoes receiving the least water matured their fruits slightly earlier than those receiving heavier applications for the season.

Fruit Cracking

Concentric cracking is typical of some varieties, e.g., Earliana, whereas radial cracking appears in some others, e.g., Marglobe. The fruits are most susceptible to cracking at an age beginning a few days before reaching the pink stage and extending through the red ripe stage.

Practical means of avoiding fruit cracking are: harvesting mature fruits as soon as possible; maintaining a constant, plentiful soil moisture supply; producing healthy, heavy foliage; and selecting proper varieties.

Harvesting

The tomato fruit is highly perishable and tender. Intelligent picking can do much to increase profits. Frequency of picking will vary with the weather, with maturity desired, and with the purpose for which the crop is grown. Mature-green tomatoes should be picked at least once a week at the start of the season, and the field should be gone over at least twice a week or preferably every other day in hot weather after the season is well under way. When marketed in the pink and ripe stages, frequency of picking, when the ripening season is well under way, varies from every day or two to intervals of 10–12 days, according to the weather, availability of labor, and the purpose of the crop, e.g., shipping, canning, and so forth. Fewer pickings, and at longer intervals, are made for canning than for market trade. Heavy rains promote rotting and delayed ripening. Premature picking causes losses in quality. A good picker must be energetic in looking for hidden tomatoes which, if overlooked, may rot on the vine. Pickers may gather poorly colored fruit because of carelessness and lack of appreciation of quality, or because they are color blind.

Stage of maturity. Three definite stages of maturity are recognized commercially: mature green (green wrap), pink (turning pink), and ripe. Several days before any pink or red develops on the surface, tomatoes reach a stage of maturity on the vine that will ensure ripening. Fruit for shipping long distances is usually picked while "mature green" and shipped without refrigeration.

Mature-green tomatoes comprise the bulk of the shipments from the South and West. At this stage the tomato is almost fully grown and the interior ripening processes are well under way. The characteristic color develops to some extent during transit. The term "pink" or "turning pink" is applied to tomatoes with red or pink color varying from a trace at the blossom end to coverage of much of the surface. "Ripe" indicates that most of the surface is covered with red or pink but shows no indication of softness. Tomatoes picked in the pink and ripe stages have a better flavor than those picked while mature green.

In the East, there are two chief uses of green tomatoes. One is for the fresh market; the tomatoes are wrapped in paper

("green wrap") and shipped in crates to market where they are ripened in a "ripening room" or in the retailer's store. The other use is for pickling. Early yield and total yield are greater when tomatoes are harvested for green wraps than when harvested entirely at red-ripe maturity.

The higher yields are due to a larger number of fruits per plant when harvested at the mature-green stage which more than compensates for the average weight per fruit being less.[332] In the 8 days or more that the tomatoes must remain on the vines to reach red-ripe maturity they gain in size and weight (water and nutrients), but this results in a greater drain on the productive capacity of the vine so that it is not able to develop as many additional fruits. Earlier removal of the fruits results in less dropping of the remaining fruits and blossoms so that a much larger number of fruits develop to green-wrap maturity and a larger total yield results.

Picking for shipment. Mature-green fruits seem firm and will apparently stand some rough handling, but abrasions or bruises that are scarcely noticeable on them may appear as dark-brown or black unsightly spots at the market when the fruit has ripened. The shoulder is very susceptible to bruising. Paper wraps are effective in reducing shoulder bruises in transit. Using field boxes with the smooth planed side of the shook on the inside helps reduce shoulder bruises, and lining the box with smooth corrugated paper toweling or excelsior pads is even safer. If the fruit is too ripe when picked, it spoils before reaching the consumer, but the pink stage is suitable for shipment short distances without refrigeration.

Picking for canning. Tomatoes for canning are picked at the full-ripe stage, as they are canned within 24 hours of delivery. In many areas, growers are paid according to grade. Generally, a tomato must show 90 percent of the surface colored and be free from injury and disease to grade No. 1 for canning.

How to pick. The stem is left on the vine; otherwise, in the basket or market box the skin may be punctured by the stem stubs. In picking, the tomato is grasped in the hand with the thumb or forefinger pressing against the stem and is separated from the vine by a half turn or twist. Tomatoes are easily separated from the vine even while mature green, as a layer of corky cells develops at the union of stem and fruit. This layer

forms on the outer rim of the stem and extends inward; after the tomato is picked it appears as a brownish rim in the stem eye. In sorting, fruits with a very narrow brownish ring or with a greenish-white cast in the entire stem-eye area may be discarded as immature.

Some simple rules for making movements count in picking are: [141]

1. *Use a handle on the hamper.* Use a wire handle with a comfortable handpiece. The wire should be stiff, about 1/5-inch diameter. Move the hamper with an easy movement of one hand. Carry the hamper to the road, keeping the arm and back straight. Lift with the strong leg muscles. Do not move the hamper by gripping the edge of it with the fingers. It is much easier to grasp and move forward with a handle. Do not carry the hamper to the road with the arms bent and the hamper held out in front of you.
2. *Pick with both hands.* Pick with both hands close together standing with the knees slightly bent. Or pick with both hands close together and squat. When picking is done with the hands far apart, the picker cannot see what he is doing. Do not pick with one hand while the other only holds the hamper. If you do this, you can pick only 83 hampers in the time in which you should pick 100. Do not let one elbow rest on your knee while the hand only holds tomatoes. If you do this, you can pick only 86 hampers in the time in which you should pick 100.
3. *Pick as many tomatoes as possible in each hand before moving the hands to the hamper.* First, pick one tomato in each hand. Then shift the tomatoes back into the palms of the hands. Then pick a second tomato in each hand. And then move the full hands to the hamper. Do not move the hands to the hamper with only one tomato in each hand. If you do this, you can pick only 90 hampers in the time in which you should pick 100.
4. *Pick two rows across the field and keep the hamper in front of you.* Set the hamper in front of you between two rows. Keep it within easy reach. Do not set the hamper so far ahead that you have to stretch your body or throw the tomatoes. Do not get in front of the hamper so that you have to turn your body.

There are no definite rules for determining the proper maturity of tomatoes for mature-green shipment. But the grower should look for these characteristics: maximum size for the variety; development of a corky stem scar; on an immature fruit, the skin can be rubbed off, but this is not true of a mature green; when a mature-green fruit is cut with a sharp knife, the seeds are hard enough not to be cut.

Packages

The lug box ($6\frac{7}{16} \times 13\frac{1}{2} \times 16\frac{1}{8}$ inches, inside) is the chief package for carload shipments of green-wrap stock. A cleat $1\frac{1}{16}$ inch thick at each end of the lug will protect the tomatoes from pressure by the lid. The rectangular and regular shape of the lug permits easy loading in cars. The lug is designed to hold 3 layers of graded medium or large tomatoes which weigh about 30 pounds net. The size of the fruit is designated by the number of fruits in the top layer. For example, a top layer with 5 rows of tomatoes extending crosswise and 6 rows extending lengthwise is called a 5×6 pack.

As received in the primary markets in varying stages of maturity, green tomatoes are processed to develop the proper merchandizing maturity and are then repacked for distribution. Some are repacked in the original lug box, and some in 10-pound units, but most of them are now put up in consumer units, carton-like tubes or trays, holding 3 or 4 and sometimes 5 tomatoes of fairly uniform size, and packed in carriers holding 10, 20, or 30 units.

In Ohio, tomatoes move to market in the 8-quart fiberboard basket; in the East North Central States, 12- and 16-quart fiberboard baskets are used to some extent; in the South, 12- or 16-quart diamond-weave splint baskets with overhandles are favored, though some 8-quart baskets also are used.

The 12-quart climax basket is used in various Northern States, e.g., New Jersey, Pennsylvania, New York, Michigan, and Indiana. The western peach box ($11\frac{1}{2} \times 16 \times 4\frac{1}{2}$ inches) is a container for nearby markets in Washington and Oregon.

Round stave baskets ($\frac{1}{2}$ or 1 bushel) are sometimes used for transporting tomatoes to market. In deep packages, ripe tomatoes may crush. The 4-basket straight-sided crate is often used for early shipments from some areas in California. It holds 4 square till baskets containing 3 quarts, or approximately 5 pounds each. The 20- and 40-pound nailed wooden boxes are used in Atlanta, Ga., for repacking tomatoes for redistribution in the surrounding territory.

In Canada, tomatoes are usually marketed in 6- or 11-quart baskets. If the tomatoes are shipped they are covered with a lid.

Artificial Defoliation

Late in the season there is often too much foliage still on the vines. Much of the crop may be wasted unless a light frost occurs to reduce the foliage. Lack of aeration under the vines may result in much rot to the nearly ripe fruits, and pickers often avoid fields of heavy vine growth because of the extra labor needed to handle vines and to find the tomatoes. Defoliation with a calcium-cyanamide ingredient (25–30 pounds per acre) gives good results if done after September 10, i.e., when the period of sunshine is on the wane. Sunburning at that time of year is not generally serious. Defoliation enables pickers to harvest more tomatoes with less labor late in the season; this may mean the difference between getting or not getting the field picked.

Gray-Wall

Gray-wall is a serious problem in producing mature-green tomatoes in California.[235] The chlorophyll does not always accumulate uniformly and so gives a mottled appearance. The affected fruits often show a grayish surface and a relatively "thin wall" or pericarp on the side most exposed to the sun.

During the main production period in California intense sunlight persists day after day, whereas in the East there is invariably some cloudy weather though the temperature on certain days may be as high. Accompanying the high light intensity is a heat effect. Thin-wall fruit is a result of this heat effect. Exposed portions of the fruit often attain wall temperatures of 115°F., whereas the shaded portions are 10–20°F. cooler. Water moves out of the wall tissues of the exposed side. The sun heat raises the vapor pressure of the tissue on the exposed side so much that a vapor-pressure gradient exists between the exposed and unexposed portions and water is distilled from the exposed side to the interior or to the shaded side of the fruit. Since a yellow or discolored area occurs in the pericarp of the ripe fruits that in their mature-green stage show gray-wall but no external evidence of sun injury, the thin-wall condition may be a case of mild sunscald.

If the thin-wall condition is pronounced, the wall may be so weak as to suffer injury or collapse in shipment and later han-

dling. Also, the yellow area sometimes present in the wall of the ripe tomato at the place where gray-wall occurred detracts from the appearance of the sliced fruit.

Types with abundant foliage that gives good shade protection to the fruit should be grown in California. Efforts should be made to control diseases and insects that would cause defoliation of the plants and exposure of the fruit. Fertilizer, especially nitrogen, may increase the amount of foliage and thus reduce the amount of gray-wall. In picking, one should not throw the vines over and thus expose the fruits.

Storage

Fruit picked mature green can be kept 2–3 weeks at 55°F. Then, at 70°F. ripeness will be attained in another week. Temperatures lower than 55°F. promote internal breakdown and rot unless the storage period is brief.

Tomatoes picked green and allowed to ripen differ in flavor and slightly in composition from vine-ripened fruit. Those picked green are slightly more acid and contain less sugar. In artificially ripened tomatoes the process, though conforming in general to vine ripening, nevertheless fails to bring the fruits to the same degree of ripeness. In those picked at the turning stage, the ripening process compares more favorably with vine ripening.

After a tomato is picked, it continues to consume "food," which the plant can no longer furnish, for respiration; hence the fruit slowly decreases in weight. At ordinary temperatures tomatoes decrease at least 40 pounds per ton in each 24 hours after they are picked; bruised tomatoes decrease 100 pounds per ton each day.

Green tomatoes are often picked when there is danger of killing frost and stored until they ripen. Sound fruits, preferably with stems on, should be chosen. They are placed in single layers in trays or in shallow boxes in a dark, cool place at a uniform temperature; the trays may be stacked one above the other. Green-ripened tomatoes are not equal in flavor to vine-ripened ones and may be insipid. Moreover, such tomatoes do not ripen at one time, and it is necessary to sort them frequently.

Mature-green tomatoes picked just before a frost in the field ripen in storage more quickly and develop less decay than those

picked the day after a frost. The freezing point for both green and red tomatoes in storage is 30.5°F.

Insect and Disease Control

Tomato fruitworm, a green or brownish worm up to 1¾ inches long, with light stripes, eats holes in the fruit and buds. Controls are: dusting with DDT; applying poisoned bait when the plants are 1–2 feet across or as soon as fruits of the main crop begin to set.

Hornworms are large, green, smooth caterpillars with a horn-like structure on their hind end. One worm may defoliate an entire plant. Hand picking may suffice. DDD is effective. Rotenone may be safer after tomatoes are half grown.

Aphids, flea beetles, and *Colorado potato beetle* are discussed elsewhere in the text.

A. Diseases affecting leaves and stems, with or without symptoms on fruits.[106]

1. Wilting of plant, without definite leaf spots.
   - (*a*) Yellowing and death of leaves from base upward; single shoots often killed before serious infection of others; stem brown inside: *Fusarium wilt.*
   - (*b*) Yellowing and loss of leaves at base of shoots; plant stunted; discoloration of woody tissues of lower part of stem: *Verticillium wilt.*
   - (*c*) Dark watersoaked decay of center of stem just aboveground; plant dying: *Bacterial wilt.*
   - (*d*) Upward rolling of leaflet margins; leaves browning and drying progressively up the stem but remaining attached; one side of plant often attacked first; stem with open cankers and yellowish mealy decay of inner tissues; white-ringed spots in peel; small cavities in center of fruit: *Bacterial canker.*
   - (*e*) Gradual dropping of leaves; stem decayed at ground line and covered with whitish fungus, with small, light-brown bodies: *Southern blight.*
   - (*f*) Decay of soft tissues of stem; cavities contain whitish fungus and black sclerotia; fruit sometimes with watery, soft rot: *Stem rot.*
   - (*g*) Emergence failure or collapse of seedlings caused by decay of stem at ground line or of roots: *Damping-off.*
2. Leaf spots but no wilting of plant; little or no spotting of fruit.
   - (*a*) Circular spots with dark margins and gray centers dotted with dark specks on older leaves; often serious defoliation: *Septoria leaf spot.*
   - (*b*) Large, yellowed patches on older leaves; olive-brown, velvety coating of the fungus on lower sides; much foliage killed: *Leaf mold.*
   - (*c*) Many dark-brown to gray-brown spots through the leaf; yellowing, withering, and dropping of leaves: *Stemphylium leaf spot.*

3. Leaf spots and spotting or decay of fruit, but no wilting of plant.
   (*a*) Spots on leaves brown with concentric rings; partial defoliation; dark spots with light centers on stem; fruit with large, dark, leathery spots near stem end, and dark, dry, deep decay of flesh: *Early blight.*
   (*b*) Leaf and stem symptoms as in Early blight; small, slightly sunken spots with dark margins and gray-brown centers on fruit; decay shallow: *Nailhead spot.*
   (*c*) Small, dark, irregular, greasy-like spots on leaves, often tearing out; defoliation sometimes serious; spots on green fruit raised, water-soaked, later sunken, light brown, rough, shallow: *Bacterial spot.*
   (*d*) Many minute, dark spots extending through leaves; dark, slightly raised specks on fruit: *Bacterial speck.*
   (*e*) Greenish-black, watersoaked patches on older leaves; much defoliation; spots at stem end of fruit may cover half the surface: *Late blight.*
   (*f*) Dark spots with concentric markings on leaves; dark, elongated spots with faint, zonate markings on stem; seedlings may die; small, depressed, brown spots near stem scar on fruit; larger, leathery, black spots on fruit ripening after shipment; spots dotted with minute pustules: *Phoma rot.*
   (*g*) Mottling of leaves and many small, grayish-brown papery spots; withering and dying of some leaves; later growth with small, irregular chocolate-brown spots; dark-brown narrow streaks on stem; brown, irregular, greasy-like spots on fruit: *Double-virus streak.*
   (*h*) Small, irregular, dark-brown lesions or linear "oak leaf" markings on leaves; later often showing only green mottling; stem sometimes with broad, brown streaks and brown, shriveled areas in pith; fruit sometimes with depressed brown rings: *Single-virus streak.*
   (*i*) Many small, circular, bronze spots on young leaves; such leaves may darken and wither; tips of young plants are sometimes killed; new growth may be stunted; spots on ripe fruit with concentric circles of red and yellow, center often raised: *Spotted wilt.*
4. Mottling, yellowing, curling, or malformation of leaflets and more or less stunting of plant.
   (*a*) Green or yellow mottling of leaves; some curling, malformation, and dwarfing of leaflets; plant slightly stunted; fruit mottled by yellow strains of virus: *Tomato (tobacco) mosaic.*
   (*b*) Pronounced stunting; bushy growth; mild, green mottle and "shoe-string" of leaflets; fruits few, small: *Cucumber mosaic.*
   (*c*) Plant yellowed, stunted, with abnormally erect stem; rolling of leaflets exposing underside; veins purple; leaves stiff, leathery; petiole curved downward; many roots killed; plant often dying: *Curly top.*
   (*d*) Older leaflets thickened and rolled upward at base; purple veins and margins; young leaves narrow, dwarfed, curled upward at tip; abnormally numerous blossoms; fruit yellowish red, soft: *Psyllid yellows.*

(e) Plant dwarfed, sickly, often killed; swellings on roots: *Root knot.*
(f) Older leaflets rolling upward and inward at margins: *Leafroll.*

B. *Diseases and disorders affecting only the fruit.*

1. Rot of the fruit.
   (a) Ripe fruit with slightly sunken, watersoaked, dark, circular spots; older spots with concentric markings; center with dark specks; sometimes colored pinkish by masses of spores: *Anthracnose.*
   (b) Grayish-green or brown, watersoaked spots without definite margins, often covering half of fruit: *Buckeye rot.*
   (c) Sunken brown spots with narrow, dark, concentric markings on fruit at or near soil; center of spot may break open: *Soil rot.*
   (d) Rot after any skin injury; often fermentation odor: *Minor fruit rots.*
   (e) Brown or black sunken spot in blossom end: *Blossom-end rot.*
2. Cracking, spotting, or malformation of fruit, but only secondary infection rot.
   (a) Yellow or whitish patches on part of fruit exposed to sun: *Sunscald.*
   (b) Fruit flattened, irregular, blossom end rough: *Catface.*
   (c) Fruit slightly flattened at sides, soft, and light in weight; large cavity between outer wall and central portion of fruit: *Pockets.*
   (d) Whitish to yellow spots just below epidermis of fruit showing glistening white masses of cells upon removal of skin: *Cloudy spot.*
   (e) Small, shallow, dark pits on fruit, often massed and forming streaks from shoulder toward blossom end: *Fruit pox.*
   (f) Whitish rings about 1/8–3/16 inch wide scattered on fruit: *Ghost spot.*

Early blight (target spot) is chiefly spread by wind and by mycelium within the seed. Controls are: seed treatment (see Table 5), disinfecting the seedbed, avoiding close rotation with other solanaceous plants, applying a carbamate at 10-day intervals. Staked tomatoes resist the disease, owing to the better air circulation and lower humidity around the plant.

Leaf spot is checked by crop rotation, destruction of crop refuse, and applying a fixed copper or a carbamate. *Nailhead* is largely overcome by growing Marglobe.

Bacterial canker is checked by a 5-year rotation and a 4-day fermentation in seed extraction. The acetic acid soak calls for a 0.9 percent solution with freshly extracted seed, or 0.6 percent with dry seed, for 24 hours at 70°F. or below. The alcohol treatment calls for immersion of dry seed in 30 percent ethyl alcohol for 10 minutes. For moist heat, the seed is soaked in a water bath held at 129°F. for 1 hour.

Bacterial spot controls are: rotating crops, treating seed for 5 minutes in 1-3,000 corrosive sublimate, and applying a carba-

mate. *Bacterial wilt* controls are: disinfecting the seedbed; at least a 4- or 5-year rotation not including potato, pepper, or eggplant; and destroying all infected plants. *Fusarium wilt* highly resistant varieties include Pan America, Southland, and Jefferson. Marglobe, Rutgers, Pritchard, Pearson, and Break O'Day are somewhat less resistant but usually make fair crops on infested soil.

Verticillium wilt control involves sanitation, such as burning affected plant and avoiding seed from plants affected by this wilt, and a 4- or 5-year rotation.

Anthracnose is avoided by a 4-year rotation, destroying all diseased fruit as soon as noticed, keeping the fruit off the ground, and applying a carbamate at 10-day intervals after the disease appears.

Damping-off is reduced by seed treatment (see Table 5).

Southern blight affected plants should be burned. Plants should not be grown in seedbeds or fields where the disease has occurred within 4 years.

Curly top is chiefly serious in the West and is spread by beet leafhoppers. Double-hill plantings, 6 inches apart in the hill, and elimination of Russian thistle are controls.

Blossom-end rot is avoided by an even supply of soil moisture, deep rooting, and ample phosphorus and calcium. Excessive use of nitrogen fertilizer, particularly stable manure, should be avoided.

Late blight is partly controlled by spraying or dusting with a fixed copper, nabam, or zineb, first about 30 days after the first blossoms appear (unless disease appears earlier) and repeating every 7–10 days. Key pathologists can warn in advance when to be ready to protect the crops. Tomatoes should not follow potatoes in the field, and it is better not to locate these crops in adjacent fields.

Mosaic is spread by handling or brushing plants and by plant lice. It is wise to avoid handling young plants unnecessarily and not to smoke while working with seedlings, since smokers may carry the virus on their hands. Washing the hands with soap and water removes the virus.

Nematode control is discussed in Chapter 15.

PEPPERS

Peppers are grown for the pod, which is used either green or ripe. There are two classes: *mild,* used for salads, pickles, baking, and stuffing; *hot,* used for relishes, seasoning, and sauces. Both of these are distinct from the black and white peppers of commerce which are derived from the fruit of *Piper nigrum,* a tropical woody plant. Cayenne or red pepper is the dry fruit of small, pungent, or chili varieties ground to a fine powder. Pepper sauce consists of the fruit of pungent types preserved in brine or vinegar. Tabasco sauce is the juice of very small, extremely pungent types, expressed by pressure. Paprika is made from the fruit of the long-podded, mild Hungarian type, ground after the seeds have been removed.

The anglicized term "pimento" ("pimiento" in some areas) often designates a type with oblate fruit, such as varieties of the Tomato group or, as in Georgia, varieties with conical-shaped fruit of the Perfection group. The word "chili" is Spanish for any kind of pepper; but on the North American continent the term is limited to mildly pungent varieties used mostly in the dry state for flavoring other foods.

History

The early history of the pepper closely parallels that of the tomato. Red peppers were as popular as a food condiment among the ancient inhabitants of the Americas as they are today in Mexico and the Andean highlands, in the form of chile con carne, hot tamales, and other mouth-burning preparations.

Tropical South America, especially Brazil, was the original home of the various forms that, through crossing and natural variation, have given the present varieties. Many forms were cultivated and used as food in South America and Mexico before the coming of the white man.

Peppers were not known in Europe before the discovery of America. There is no ancient Sanskrit of Chinese name for the genus. The Greeks, Romans, and Hebrews were not acquainted with it.

Approximate dates when the varieties became known are as follows: 1542, Cayenne; 1586, Cherry; 1588, Chili; 1731, Celestial;

1774, Bell (Bull Nose); 1813, Long Red; 1828, California Wonder; 1849, Sweet Mountain; 1882, Golden Dawn; 1884, Ruby King; 1887, Cardinal; 1888, Tabasco; 1900, Chinese Giant; 1903, Anaheim Chili, Neopolitan; 1904, Magnum Dulce; 1906, Ruby Giant; 1912, Perfection; 1918, Royal King; 1919, World Beater; 1920, Harris Earliest; 1922, Sunnybrook; 1935, Asgrow King; 1937, Windsor A; 1938, Rocky Ford; 1941, Sweet Banana; 1943,

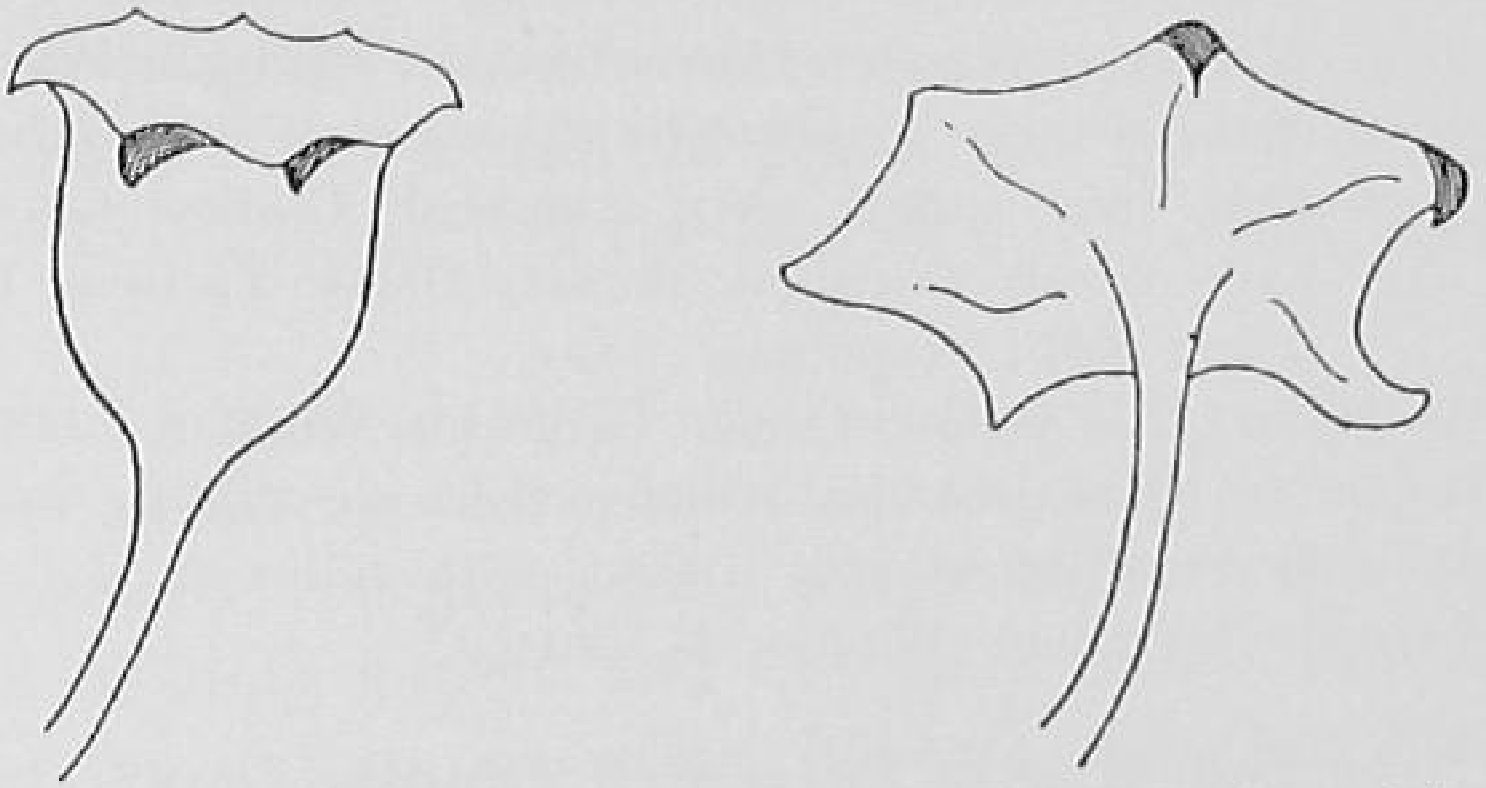

FIG. 65. *Left,* cup-shaped calyx. *Right,* saucer-shaped calyx. The pod and placenta have been removed. (*After Erwin.*[124])

Early Pimento, Truhart Perfection; 1945, Pennwonder; 1946, Tuscany, Patrick Henry; 1951, Vinedale.

The hot varieties have been known for 250–300 years and even longer. Among the sweet varieties the names of Bell or Bull Nose, Ox Heart, and Squash have been current for more than 150 years.

Classification and Varieties

A. Calyx embracing base of fruit or cup shaped.
1. Fruit linear and erect: *Tabasco or Chili group*—Tabasco, Chili Dwarf, Japanese Cluster, Orange Red Cluster, Red Chili.
2. Fruit elongated, conical, and pendent: *Cayenne group*—Long Red Cayenne, Anaheim Giant Chili, Long Red, Heifer Horn, Hot Portugal.

B. Calyx pateriform or saucer shaped.
1. Fruit globose: *Cherry group*—Cherry, Bird's Eye, Red Cherry, Yellow Cherry, Creole.
2. Fruit conical.
   (*a*) Fruit erect: *Celestial group*—Coral Gem, Spanish Gem, Little Gem, Floral Gem, Prince of Wales.
   (*b*) Fruit pendent.
      (i) Immature fruit green: *Perfection group*—Early Pimento, Perfection (Pimento), Hungarian, Paprika, Truhart.

(ii) Immature fruit yellow: *Banana group.*

a. Sweet or slightly pungent: Roumanian, Sweet Banana, Hungarian Wax.

b. Pungent: Hungarian Yellow Wax, Banana (Long Hot Yellow).

(*c*) Fruit oblate: *Tomato group*—Sunnybrook (Sweet Cheese, Squash), Topepo, Red Apple.

(*d*) Fruit blunt-ended and blocky: *Bell group.*

(i) Mature fruit red.

a. Flesh medium to thick; surface smooth, uniform: California Wonder (Florida Giant, Wonder Giant), Early California Wonder, Calwonder, Harris Wonder, Michigan Wonder, Merrimac Wonder, Pennwonder, Tuscany, Waltham Beauty.

b. Flesh thin; surface often crumpled: Chinese Giant, Harris Early Giant, Hamilton Market, Harris Earliest, Bull Nose (Large Bell), Neapolitan.

(ii) Mature fruit yellow: Golden California Wonder, Golden Dawn, Golden Queen, Golden Wonder, Oshkosh, Prolific Yellow.

(*e*) Fruit intermediate to long conical, with blunt to pointed ends: *Extreme Bell group*—Windsor A, Vinedale.

Ruby King, Bull Nose or *Large Bell, Chinese Giant, California Wonder,* and *Golden Dawn* are leaders in the large-fruited, mild-flavored group. *Perfection* is smaller, and is much used for canning. Other good sweet peppers are *Oakview Wonder, Early Calwonder, Windsor A, Pennwonder, Tuscany, Patrick Henry, Early Pimento,* and *Sunnybrook. Merrimac Wonder* and *Vinedale* are noteworthy early varieties. The *Bell* peppers constitute the mangoes of commerce; these large-podded "sweet" peppers are used either in the green or in the mature stage for stuffing, salads, etc. Leaders in the smaller-fruited types, including the hot peppers, are *Chili* or *Red Chili, Cayenne, Anaheim* and *Tabasco.* Hot peppers are popular in the warmer regions of the South, especially among people of Spanish descent, to flavor foods and as a condiment.

Plant Characteristics

Peppers are perennials in the tropics but are grown as annuals in temperate zones. The plant commonly grows 1–2½ feet tall and has glossy, somewhat elongated heart-shaped leaves. Night temperature is apparently the limiting factor in many growth phenomena of the pepper plant, as it is in the development of the tomato plant.[107]

After 6–10 weeks in the hotbed, with good care, the plants are ready for the field. The taproot is usually more or less damaged in transplanting. From the remaining short portion of it and the base of the stem may arise many laterals that eventually constitute an efficient absorbing system. After 60 days in the field the roots may occupy the soil around the plant to a depth of 10–14 inches. In Georgia by late August the larger and more deeply penetrating roots extend outward 40 inches from the base of the plant and downward as deep as 26 inches. There, roots of mature or 8-month-old plants may spread 48–52 inches on each side, with many of the laterals in the second foot of the soil.

Failure of pepper plants to set fruit properly is a serious problem in certain areas. Low humidity and high temperatures result in excessive transpiration, a water deficit in the plant, and abscission of buds, flowers, and very small fruits. Low moisture supply in the soil also promotes blossom drop, but with excessive transpiration a water deficit develops even when the soil is well supplied with water.

The fruit is a pod-like berry, borne on a short, stout peduncle, erect at first but in some types becoming pendent. Immature fruit is yellowish to deep green owing to the chlorophyll in the outer layers of the pericarp. The pigment of red peppers is a mixture of lycopene, xanthophyll, and carotene; the last alone is present in yellow types.

Inheritance studies [292] have shown: (*a*) Immature fruit color is conditioned by several "cumulative" factors. When two or more pairs of these factors are dominant, the fruit is cedar green, and when all are recessive the fruit is sulfury white. (*b*) A short peduncle hinders a positive geotropic response. (*c*) Calyx shape inheritance is somewhat complex. Size of fruit is associated with calyx type. (*d*) True breeding nonpungent strains are readily obtained from crosses between pungent and nonpungent types. (*e*) True breeding early strains are readily recovered. (*f*) The dates of first flower to open and ripening of the first fruit are closely associated.

The pungency of peppers is due to capsaicin (an acrid, volatile alkaloid soluble in alcohol). Pungency is most pronounced in the small-fruited forms, e.g., Tabasco; only traces occur in thick-meated, large-podded forms, e.g., Tomato group. The formation of capsaicin is a function of the ovary wall in general, and the greater concentration in the placentae and seeds in the later stages

of the fruit is a matter of transportation to the most important centers of growth.[389]

Producing Peppers

Climate and Soil

Pepper plants are a little hardier than eggplant but slightly more tender than tomato, although they tolerate extremes of heat and dryness better than either of these crops. Peppers thrive best in warm climates where there is little danger of frost injury and need a long, warm growing season. The number of days from seeding to maturity differs with varieties and areas; it commonly is 120–150 days; in Georgia, 90–110 days are required after setting in the field.

Peppers are not planted in colder areas until the soil has warmed up and danger of frost is over. A light, warm soil fairly retentive of moisture is best. Soils conducive to earliness are essential in short-season regions.

Starting the Plants

Because of the long growing season needed and their sensitiveness to frost, pepper plants are always started in a greenhouse or hotbed in the North. In the South, early plants are usually grown in cloth-covered steam- or hot-water-heated frames; plants for later use are grown in frames or outdoors. In the Southwest, Chili peppers are seeded in the field. In Georgia, which ranks first in pimento acreage and production, three general methods are used for growing plants: (*a*) the hotbed method, e.g., for the plants grown in the Piedmont area; (*b*) the coldframe method; and (*c*) the open-field method. The last two are used by growers and canners in southern Georgia where supplementary heat is not needed.

Electric cables are convenient for heating hotbeds. In Georgia,[145] four 60-foot lengths (8 strands) are used to heat a 30×6 foot bed and, similarly, four 120-foot lengths for a 60×6 foot bed. When provided with a thermostat, these units are automatic.

Pepper seed germinates slowly. It is usually 8–12 days before seedlings appear, but in some cases, as with seed stored under

comparatively unfavorable conditions or under cool temperatures, a longer time is needed. No germination may occur at 40–50°F. Soaking the seeds for 5 hours in water at 71°F. before sowing gives little or no increase in rate and does not always increase the percentage of germination. In general, the hotbed should be kept at 80–85°F. for the first 2 weeks for quick germination.

With 80 percent germination, 2 ounces of seed will produce enough plants for 1 acre. But allowing for replants, a reasonable amount of damage when the plants are pulled from the hotbed, and some loss from diseases, at least 4 ounces of seed should be sown to secure enough plants to set 1 acre; in Georgia, ½–1 pound is suggested for the hotbed method.

Pepper seed is sown 6–10 weeks before the plants are to be set outdoors. After danger of frost is over and the weather is warm, the plants are set 12–18 inches apart in rows 2½–3 feet apart. The usual spacing of pimento plants in Georgia is 2½ feet in rows 3½ feet apart. A 2½-foot spacing requires 4,978 plants, and a 3-foot spacing 4,149 plants per acre. Closer spaced plants usually grow too tall and are easily broken by wind and careless tillage. Also, the fruits are often off type in shape, and have thinner walls than those from less crowded plants.

Manure and Fertilizer

Fertile soils well supplied with humus are desirable. The seedlings should receive a light application of a mixed fertilizer when they are several inches high in the beds. For the field, 500 pounds of a good mixed fertilizer per acre may be applied in the row prior to planting. About 4–6 weeks before harvest, a sidedressing of a quickly available nitrogen fertilizer may often be applied to advantage. Heavy applications of nitrogen fertilizer may increase growth and delay maturity.

Cultivation

Tillage should be started before the weeds can become established and compete with the crop for moisture and nutrients. Cultivation beyond that needed for weed control may do more harm than good, especially if practiced late and comparatively deep.

Harvesting

The fruits are picked by snapping off the brittle stems by hand. In Georgia, cotton-picking sacks strapped over the pickers' shoulders allow for the use of both hands, are easier to carry, and have a greater capacity than baskets. Peppers are usually shipped in 1-bushel tub baskets or 1-bushel hampers.

Maximum quality in pimentos[80] is reached when the fruits remain on the plants until the color becomes dark red. Because fairly ripe fruits can remain on the plants for some time without serious deterioration, except during wet weather when they crack badly, they may be left until there are enough to make the picking of the whole field worthwhile. Fruits picked before they attain a full red color should be spread out in a dry room until they develop more color. From 14 to 18 pickings of ripe fruits, generally picking once a week, are usually made each year in Georgia. In preparing the fruit for canning the epidermis is removed by a roasting process. Hot peppers for sauce and similar preparations are allowed to ripen before they are gathered and used.

Storage

Green peppers can be ripened artificially at 71–77°F.

Peppers can be kept in good condition for at least 40 days at 32°F. and 95 percent relative humidity. Shrinkage under these conditions is only 4 percent in 40 days, less than for most vegetables. At 40°F. peppers keep well for about 4 weeks and at 50°F. for about 2 weeks. Above 50°F. breakdown is caused by softening, wilting, and shriveling. Peppers freeze in storage at 30.1°F.

Chili peppers are dried in 2–3 days in kilns at about 130°F., in thin layers in stacked wire-bottomed trays. When ground, such dried peppers become the red pepper of commerce.

Insect and Disease Control

Hornworms (see under Tomato) sometimes attack peppers.

Bacterial spot, in the seedbed, shows as black spots along the margins of cotyledonary leaves; new leaves are shed. In the field, the leaves are covered with spots, turn yellow, and drop. On the

fruit, the spots are at first yellow and blister-like. The surface of the blister cracks and becomes ridged, rough, and cankerous. The pods are unfit for market but seldom drop. Controls are seed treatment (see Table 5), spraying with a carbamate in the seedbed and later, rotation of crops, destruction of pepper or tomato refuse, removal of infected plants, and deep plowing.

The foregoing treatments also help control a number of other pepper diseases, such as *leaf spot, anthracnose,* and *damping-off.*

Blossom-end rot control is the same as mentioned for tomato.

Mosaic of peppers may be caused by either the cucumber mosaic or tomato mosaic virus (see under these crops). Burlington and Rutgers World Beater No. 13 are resistant to tomato mosaic but not to cucumber mosaic.

EGGPLANT

The eggplant, or Guinea Squash, is greatly esteemed by some, disliked by others, and unknown to many. It holds an important place in China, India, and Japan. In the Balkans, southern Europe, and the lands contiguous with the Mediterranean Sea, eggplant is a staple vegetable. In France, too, it is a favorite dish, especially in the Southeast, where the Provençal, like his Italian neighbor, regards it as one of the garden's best productions. In America, it is grown as a truck crop chiefly in Florida and Louisiana, and to a limited extent in areas farther north.

Plant Characteristics

The eggplant has large purple fruits (often 7–8 inches long and 4 inches thick), bushy plants, woody stems, leaves that are large and alternate, and flowers that are 1–2 inches across, violet in color, and solitary or in clusters of two or more. The plants usually grow 1½–2 feet high, but some such as Florida High Bush may grow 2½–3 feet tall.

The fruit is a pendent, fleshy berry. The purple pigment is probably anthocyanin in a thin layer of subepidermal cells. The epidermis of the fruit is smooth and is shiny when its slight covering of waxy bloom is rubbed off. The seeds are embedded in the placentae, a spongy mass, which constitutes most of the flesh of the fruit.

History

The eggplant originated in India, with a secondary center in China. It may have been introduced to Europe by the Moorish invaders of Spain. It did not reach England until 1597. In India it is known as *bringal,* and in France as *aubergine.*

In 1856, Vilmorin-Andrieux & Co., in France, described Long Purple, Chinese Long White, Large Purple (of American origin), and Guadalupe Striped. In 1865, Burr, in the United States, listed New York Improved as well as the preceding ones. Black Pekin came from China in 1870. Black Beauty appeared in 1900. Florida High Bush originated in Florida in 1905. Black Bountiful was brought to this continent in 1931. New Hampshire Hybrid (All-America, 1939) was developed by J. R. Hepler. Badger State (Black Beauty × Bountiful) was developed by O. B. Combs in Wisconsin in 1945. Florida Market and Florida Beauty were developed by P. Decker of the Florida Experiment Station by crossing a phomopsis-resistant Oriental type with Fort Myers Market and were introduced in 1951.

Varieties and Hybrids

A. Compact bush (height under 2 feet), early: New Hampshire Hybrid, Japanese Early Hybrid, Badger State.
B. Medium tall (24–30 inches), midseason to late: Black Beauty, Improved Long Purple.
C. Highbush (over 30 inches), very late: Florida High Bush, Fort Myers Market, Creole, New Orleans Market, Manatee Special, Florida Market, Florida Beauty.

Producing Eggplant

Climate and Soil

The eggplant needs a long growing season with high average day and night temperatures. The soil must be well warmed up before the plants can safely be set outdoors. Soil for the eggplant must be quite fertile, but it is not wise to use fresh manure or excessive amounts of fertilizer.

Raising the Plants

The culture of the eggplant is much the same as for the tomato and pepper, but it needs a longer and warmer growing season

and is more seriously checked in growth by cool weather. The plants are rather sensitive to transplanting, and special efforts, such as the use of plant boxes, may be wise.

The seed germinates slowly and is sown in the greenhouse or hotbed at 65–70°F., 8–10 weeks before the plants are to be set outdoors. The plants must be grown without check from drought, low temperature, or other cause. They must not be set out until all danger of frost is over and the weather is warm. Good plants for setting have stems that are not hard or woody; one with a woody stem rarely develops well. Plants are set 15–18 inches apart in rows 3–4 feet apart. In short-season districts only 1–2 fruits should be allowed to develop on a plant.

FIG. 66. Eggplant. (*Courtesy Florida Agricultural Extension Service, Gainesville, Fla.*)

HARVESTING AND STORAGE

The fruit is harvested before it is fully ripe, but it should be well colored. When fully ripened on the plants, the fruit becomes greenish bronze, the flesh dry and tough, and the seed hard. Harvesting is done by cutting the fruits from the vines. The fleshy calyx and a short piece of stem are left attached to the fruit. The fruits are heavy and must be handled carefully.

Eggplant fruits are chiefly shipped northward from Florida and Louisiana. They can be kept 7–10 days in good condition at 45–50°F. and 85–90 percent relative humidity. They freeze in storage at 30.4°F.

Insect and Disease Control

Eggplant lace bug is flat, has lace-like wings, and clusters on the undersides of leaves. Large yellow spots appear on the leaves. The leaves finally turn yellow and drop. Control is dusting with sabadilla.

Colorado potato beetles, flea beetles, hornworms, and *aphids* may also cause damage. They are discussed, as well as *damping-off,* elsewhere in the text.

Phomopsis blight shows as girdling of young plants at soil level. Brown lesions occur on the leaves, and light-brown, slightly depressed lesions studded with pycnidia appear on the fruits. Weekly spraying should be done in the seedbed with a carbamate after the first true leaves develop. Plants in the field are sprayed as soon as established and weekly thereafter for 5–7 weeks.

Verticillium and *Fusarium wilts* cause wilting and stunting of plants. The lower leaves turn first yellow and then brown between the veins. If the stem is cut lengthwise, the vascular tissue is dark. A good rotation is long and avoids tomatoes, potatoes, or raspberries. Further controls are treating the seed (see Table 5) and spraying or dusting with a carbamate.

13 · VINE CROPS

PUMPKIN, SQUASH, AND VEGETABLE MARROW

Pumpkin, squash, and vegetable marrow are sensitive to light frosts, as are all vine-crop vegetables, but they are somewhat more tolerant of a cool, moist environment when young than cucumbers or melons. They need a warm, but not extremely hot, growing season. Winter types, in general, need a long growing season; summer types, because they bear earlier and are used chiefly in the immature stage, can be grown where the season is rela-

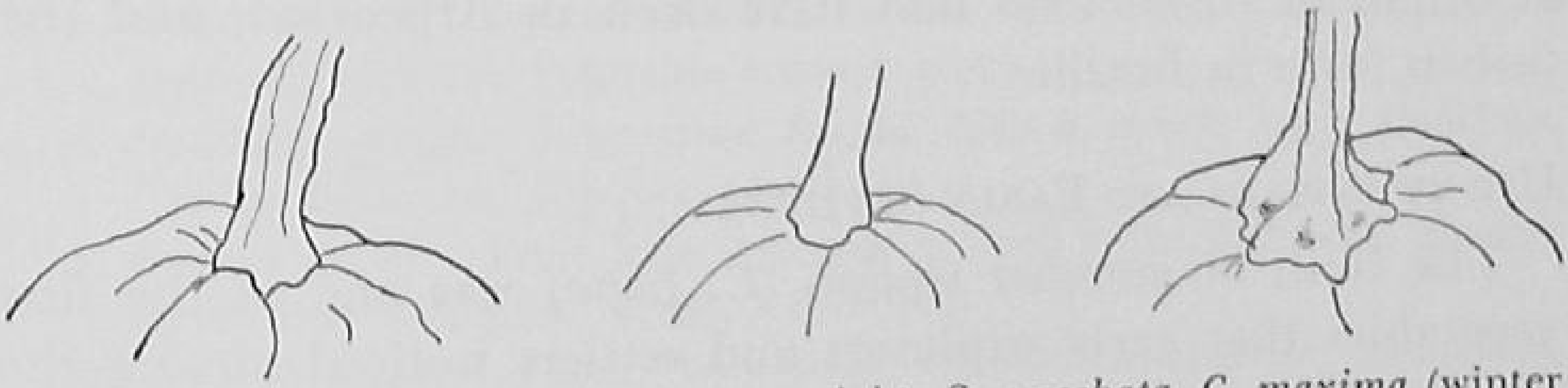

Fig. 67. Types of fruit stems. *Left to right: C. moschata, C. maxima* (winter squash), *C. pepo* (pumpkin, summer squash, vegetable marrow).

tively short. Pumpkin, squash, and marrow, and also cucumber vines, though easily damaged by fall frosts, continue to develop good-quality fruits under conditions that are too cool for the muskmelon or watermelon.

History

The Chinese call the pumpkin the emperor of the garden and use it as a symbol of fruitfulness, health, and gain.

Locations of Origin

The three species, *Cucurbita pepo, C. maxima,* and *C. moschata* are endemic to the Americas. The flowers held a sacred place in the religion of some Indian tribes, which points to a great antiquity of the cultivated plant. Evidence found in ancient

Indian tombs shows that pumpkin and squash were used as food by the Basket Makers in 2000 B.C.

Different groups of *C. pepo* have arisen independently.[426] The archeological evidence indicates that *C. pepo* entered the southwestern Puebloan area about A.D. 1000. The Puebloan cucurbit for the preceding 800 years had been *C. moschata*. The entry of *C. pepo* into the Pueblo area is associated with an expansion of the Hobokam culture of the Gila and Salt River Valleys. In the eastern United States, *C. pepo* appears on the earliest agricultural horizons and is accompanied by a unique assemblage of locally domesticated plants totally unrelated to the Hobokam assemblage. The eastern United States later obtained Mexican crops, but they were the crops of Middle America and southern Mexico rather than of northwestern Mexico.

The oldest of the three species is probably *C. moschata*. Its white-seeded forms may have come from Guatemala and central Mexico, and the dark-seeded form from Colombia. The center of origin of *C. maxima* may have been in Argentina, and the turban form in Brazil.

Use by Indians and Early Settlers

The bush or summer squash (*C. pepo*) was one of the first vegetables that early explorers and settlers noticed among the natives. The fruits were called quasiens, citroules, or cymnels. The northern Indians called them squash or squanter-squash. The Indians used the dried shell of the warted crookneck as a rattle during ceremonial dances, and from certain varieties they made colorful ornaments such as are made from gourds.

Periods of Introduction

Some varieties introduced during certain periods are as follows: before 1825, Yellow Bush Scallop, White Bush Scallop, Crookneck; 1825–1850, Cheese, Connecticut Field, Acorn, French Turban, Boston Marrow, Mammoth Chili, Hubbard; 1850–1900, Custard Yokohama, Small Sugar, Green Bush Scallop, American Turban, Marblehead, Tours, Essex Hybrid, Etampes, Green Striped Cushaw, Japanese Pie, Warren, Calhoun, Chicago Warted Hubbard, Golden Hubbard, Earliest Prolific; 1900–1925, Fordhook Bush, Delicious, Blue Hubbard, Table Queen, Zucchini; 1925–1950, Golden Delicious, Buttercup, Cocozelle,

Early Prolific Straightneck, Greengold, Butternut, Connecticut Straightneck, Golden Table Queen, Yankee Hybrid, Caserta, Uconn.

Classification and Varieties

A. Cucurbita maxima, True Squash, Winter Squash. Leaves rounded, kidney shaped, obscurely lobed or not lobed, slightly harsh or prickly; flowers with narrow, linear, thin, long calyx lobes; fruit stem cylindrical or claviform, spongy, soft, not noticeably ridged or furrowed, enlarged at its attachment to the fruit; seeds large, enameled, white or brown with the margin the same color and texture as body of seed; seed scar slanting.

1. *Hubbard group.* Fruit spherical, tapering to a curved neck at stem end and to a somewhat curved point at blossom end. (*a*) Vining: Hubbard (blue, golden, red, green, baby, and warted forms), Marblehead. (*b*) Bush: Baby Blue.
2. *Turban group.* Turban shape; button at the blossom end; often a "squash within a squash" at the blossom end. (*a*) Vining: Sweetmeat, Warren, Buttercup, Banquet, Greengold. (*b*) Bush (fruits clustered near the main stem): Bush Buttercup.
3. *Boston Marrow group.* Fruit lemon shaped, light to reddish orange color; surface irregular: Boston Marrow. (This group should not be confused with the Vegetable Marrow group.)
4. *Delicious group.* Fruit cone shaped (like a child's top): Delicious, Golden Delicious, Banquet, Quality.
5. *Banana group.* Fruit long, tapering at both ends; shell soft; Banana (gray, blue, red, pink forms), Rainbow.
6. *Show or display group.* Very large, soft-shelled varieties: Mammath, Mammoth Chili, Mammoth Whale, Etampes, Hungarian Field.

B. Cucurbita pepo, Pumpkin, Summer Squash, Vegetable Marrow. Leaves pointed, deeply indented between lobes, harsh, rough and prickly; corolla lobes awl shaped; fruit stem 5–8 sided, grooved, hard; seeds comparatively small, usually tan colored, with a horizontal or rounded scar, and with the margin of same color and texture as body of the seed.

1. *Field or Pie Pumpkin group.* Fruit orange colored, grooved, oblong, or round and flattened at both ends; trailing habit. (*a*) Trailing: Connecticut Field, Dickinson, Small Sugar, Winter Luxury, Ft. Berthold, Golden Oblong, Omaha, Tours, Sandwich Island, Early Cheyenne Pie. (*b*) Bush: Cheyenne Bush (very small).
2. *Vegetable Marrow group.* Fruit long, tapering from blossom to stem end, white, yellow, green, or striped, with smooth skin.
   - (*a*) English vegetable marrow; more popular in England and Canada than in the United States. (i) Bush type: White Bush, Green Bush. (ii) Vining type: Long Green, Long White, Cream.
   - (*b*) Italian vegetable marrow: Cocozelle, Zucchini, Caserta.
   - (*c*) Vegetable spaghetti (Manchurian squash).
3. *Summar Crookneck and Straightneck group.* Bush habit; fruit yellow or white; warty; commonly with long, curved neck, but certain strains

have straight necks: Summer Crookneck, White Summer Crookneck, Early Prolific Straightneck, Yankee Hybrid.

4. *Scallop or Patty Pan group.* Fruit flat, edge scalloped; bush habit: White Bush Scallop, Green Tinted Bush Scallop, Yellow Bush Scallop.
5. *Fordhook group.* Fruit short club shaped and longitudinally grooved. (*a*) Vining: Table Queen, Golden Queen. (*b*) Bush: Fordhook Bush, Uconn.

C. *Cucurbita moschata,* commonly called pumpkin or squash but referring to a different species than that usually grown in northern areas. Leaves not deeply indented, soft hairy, with white spots; fruit stem moderately hard, round, or smoothly 5 sided, distinctly flaring; flesh yellow to dark orange; seed scar horizontal or rounded; seed whitish to dark brown, margin scalloped: Calhoun, Cheese, Golden Cushaw, Kentucky Field, Virginia Mammoth, Quaker Pie, Butternut, Turkish Honey.

D. *Cucurbita mixta.* Fruit stem hard, basically 5 angled, rounded but moderately or not enlarged at base; flesh white or pale tan or yellow; seed white or tan-brown, margin barely scalloped: White Cushaw, Green Striped Cushaw, Tennessee Sweet Potato, Japanese Pie.

True or Winter Squash Varieties

Hubbard is the leading squash for general purposes and is often grown to the exclusion of all others. There are a number of Hubbard varieties or strains, such as Blue Hubbard, Chicago Warted Hubbard, Golden Hubbard, and Kitchenette.

Buttercup and *Greengold* are small (3–5 pounds) and good for baking in the half shell. *Boston Marrow* is productive, large, orange-fleshed, and useful for canning, especially when blended with more watery pumpkin. *Delicious* and *Golden Delicious* are of high quality. *Red Banana* is often seen on California markets. Novelties that may weigh 100 pounds are *Mammoth, Mammoth Chili, Mammoth Whale,* and *Etampes.*

Pumpkin, Summer Squash, and Vegetable Marrow Varieties

Connecticut Field is much used for blending with stiffer squash varieties in the manufacture of pie stock. *Small Sugar* is smaller and of better quality and is the noted New England pie pumpkin used during fall and at Thanksgiving.

The name English vegetable marrow really refers to a group rather than to a variety. When a person buys seed of this so-called variety, he may get different varieties according to the source of the seed. Two bush strains are *White Bush Marrow* and *Green Bush Marrow.* Two vining strains are *Long White* and *Long Green.*

Italian vegetable marrow, like English vegetable marrow, is a group. Named varieties are *Cocozelle, Caserta* (All-America, 1949), and *Zucchini.*

In *Summer Crookneck,* the light yellow fruit is decidedly curved, crooked-neck to about half the length, and has an enlarged portion in which the seeds are contained at the other end. *Early Prolific Straightneck* is more easily packed for shipment. *Yankee Hybrid* is a leading hybrid summer squash.

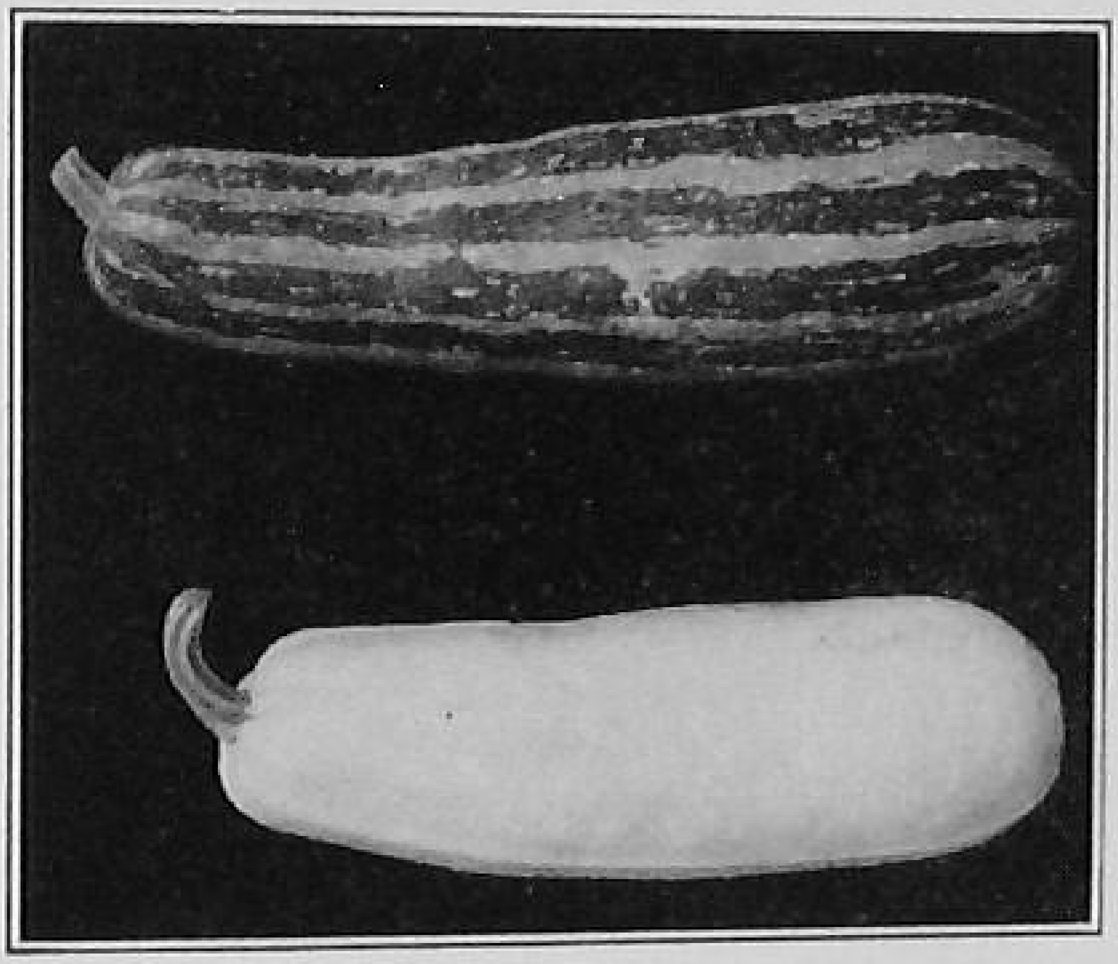

FIG. 68. English type of vegetable marrow.

The *Scallop* group is also called Patty Pan because the fruit resembles a kitchen pan.

Table Queen fruit is dark green, small (5–6 × 4½ inches), acorn shaped, smooth, and thin shelled, matures between summer and winter sorts, is a good size to cut in half and bake, and is of high quality. *Golden Queen* is slightly larger. *Uconn* (All-America, 1950) resembles Early Prolific in bush habit and earliness and Table Queen in fruit.

Butternut is dumbbell shaped and is the leading variety of its species in northern regions. Other *C. moshata,* as well as *C. mixta,* varieties, most of them popular in the South, are listed in the classification.

Plant Characteristics

Vining and Bush Habits

The plants are of two types: (*a*) vining and (*b*) bush or semi-erect. In the latter, the internodes are shorter, and tendrils are

absent. In the former, 3–8 lateral branches arise from as many nodes near the base of the stem axis and extend outward for many feet. The growth of stem and leafage within a growing period of 4 months is probably unequaled by any other annual herbaceous plant family. In *C. pepo,* a record single plant has developed growth exceeding 140 feet in total length and 450 leaves.

Bush habit: Cocozelle, Zucchini, Benning White Bush, Early Prolific White Bush, Early White Bush, Early Yellow Bush, Summer Crookneck, Fordhook Bush, Giant Summer Crookneck, Giant Summer Straightneck, Golden Custard, Long Island White Bush, Early Prolific Straightneck, Bush Scallop, White Bush Marrow, Bush Buttercup, Straightneck Summer, Long White Bush, Caserta, Uconn.

Vining habit: Fordhook Vine, Delicata, Table Queen, Vegetable Marrow Green Vining, Vegetable Marrow Long White Vine, Connecticut Field, Golden Oblong, Tours, Small Sugar, Winter Luxury, Buttercup, Boston Marrow, Banana, Banquet, Cushaw, Turkish Honey, Hubbard, Vegetable Spaghetti, Golden Delicious, Mammoth.

Inflorescence

The flowers are yellow, monoecious (having staminate and pistillate flowers on the same plant), and occur singly in the axils of the leaves. In trailing types, the staminate flowers occur near the center of the vine on long, slender stems and the pistillate flowers occur on short, ridged stems, distal to the staminate ones. In bushy types, the pistillate flowers occur near the base of the plant. The number of staminate flowers exceeds the pistillate flowers. (See Chapter 1 for Pollination.)

Fruit Color [346]

There are at least six different fruit colors in *C. pepo:* white, green, gray, cream, yellow, and orange. Also, there is a series of patterns such as spotting, lace-like work, striping, and bicolor, each of which determines the design of color distribution on the surface of the fruit.

The six known colors are not static characters, as commonly conceived in genetical studies; they are related to a developmental sequence that must be considered as a whole. To say that a given fruit is white, green, or yellow is misleading unless the specific color is properly associated with a *stage* of fruit development. Of ten major color groups six are persistent,

changing only in intensity, and four groups change in hue during development. The reaction of any given genotype can best be studied in terms of *rate* of pigment accumulation or depletion.

Regardless of whether or not fruits are similar in color at any given stage of their growth each genotype has a distinct developmental history of its own. There is a persistent white and an-

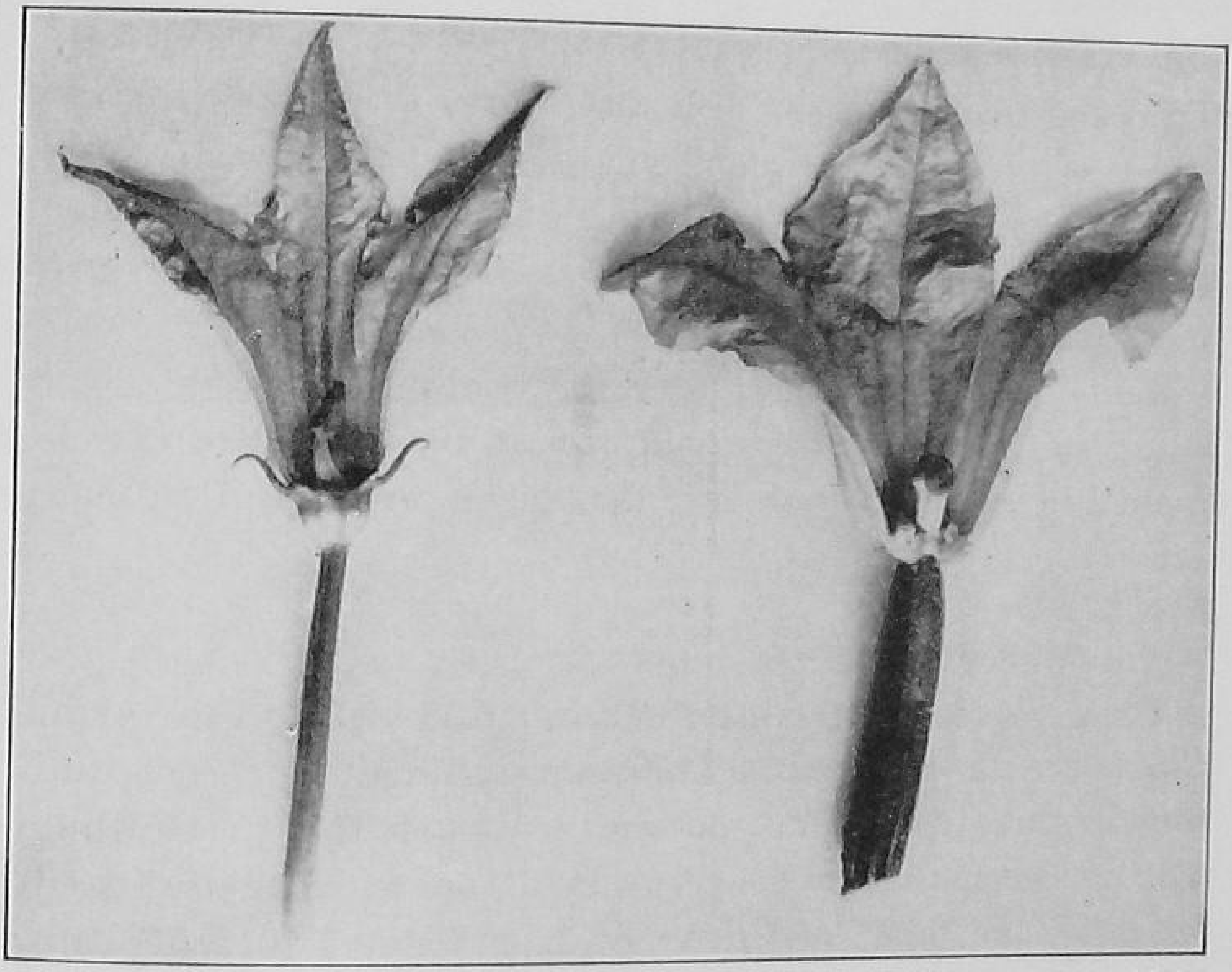

FIG. 69. Male (*left*) and female (*right*) flowers of vegetable marrow. Male flowers in the vine crops lack the young fruits that occur at the base of female flowers.

other white that is confined to early developmental stages. There are a few persistent greens as well as others that represent developmental phases, of different duration, which precede the expression of other colors. Moreover, some greens and yellows that are very similar at maturity or after maturity differ distinctly earlier in their history.

The practical implications of this analysis are obvious. In spite of the present incomplete knowledge of the genetics of fruit color, it is already possible to predict the breeding behavior of many phenotypes or to differentiate between homozygotes and heterozygotes (plants exhibiting developmental reversal of domi-

nance) by the use of a reference table that includes accurate developmental histories of known strains. Thus, it has been determined that most of the persistent color types, as well as some lines in other groups, will always breed true upon selfing.

Producing Pumpkin, Squash, and Vegetable Marrow

Soil and Fertilizer

Any soil that is well supplied with humus or otherwise fertile, not extremely acid or alkaline, and not in a frost pocket, should produce good yields of suitable types of these vine crops. When the growing season is comparatively short, lighter soils may give best results.

Manure, 10 or more tons per acre, usually is beneficial. It is spread and plowed under in autumn or, if well rotted, may be applied in spring. Potash and phosphorus are helpful on many soils.

Seeding and Spacing

The seeds do not germinate well in a cold soil, and the plants will not withstand frost. Therefore, seeding is delayed until the soil starts to warm up and until it is likely that the seedlings will not emerge before danger of frost is over. Some 6–8 seeds are sown per "hill," and these are later reduced to 2–3 plants. Thinning to 1 plant per hill may result in larger fruits, but may cause later maturity and a lower yield. The seed is sown 1–1½ inches deep.

Bush types are sown in hills 4×4–5 feet apart, or spaced about 3 feet apart in rows 4–5 feet apart. Vining types are sown in hills 8×8 to 12×12 feet apart, and seldom closer than 6×6 feet apart.

Cultivation

Cultivation should be shallow, start early, be done often enough to control weeds and keep the soil surface loose, and be continued until it would injure the vines. Some hand hoeing or weeding is likely to be needed. When the plants cover the ground they shade out many weeds.

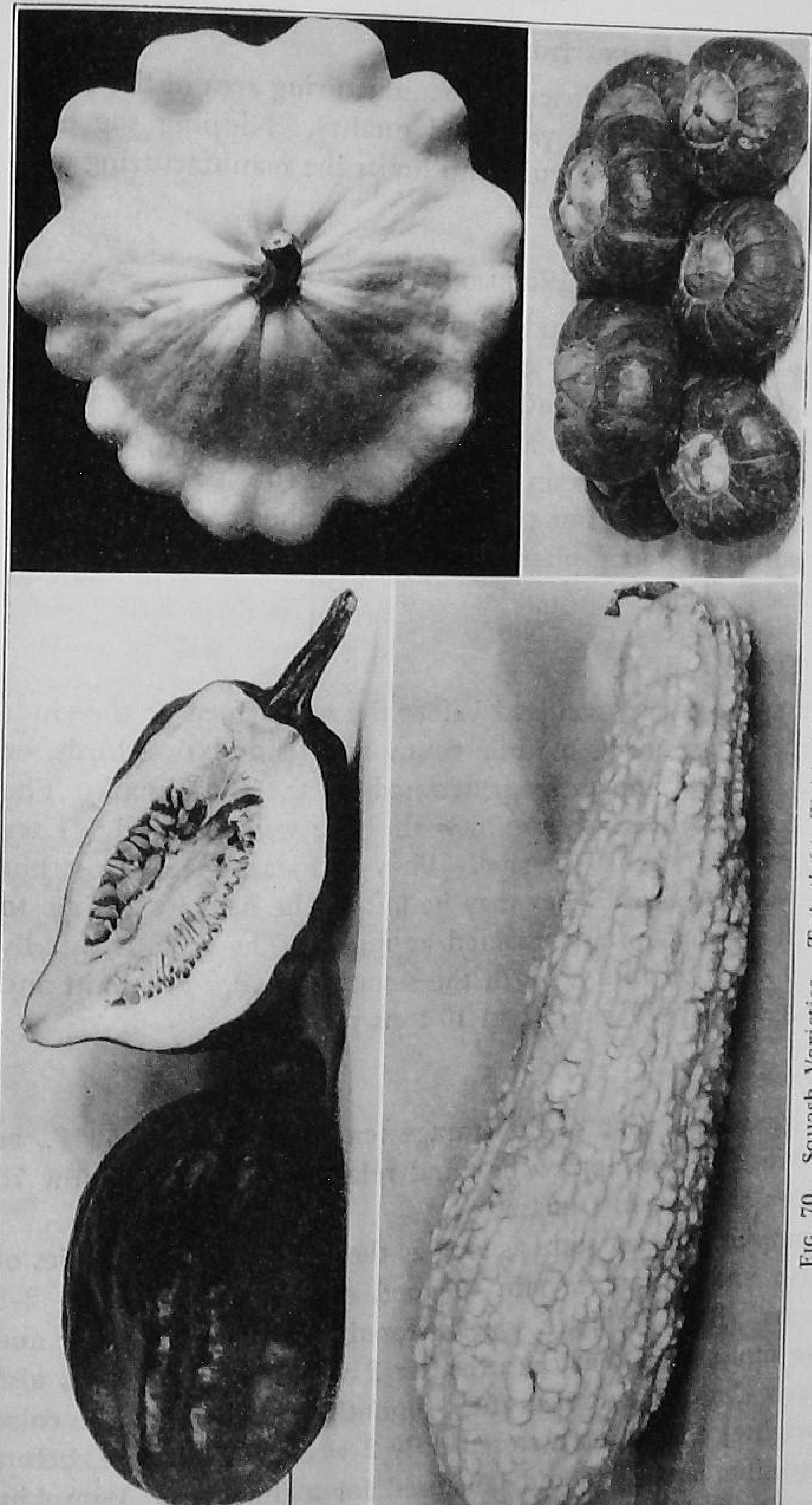

FIG. 70. Squash Varieties. *Top* (*left*), Table Queen; (*right*), Scallop or Patty Pan. *Bottom* (*left*), Crookneck; (*right*), Buttercup.

Pruning or Trimming the Leaves

Cutting off leaves reduces the manufacturing area of the plant, and so may reduce the yield and quality. Nipping the ends of the vines beyond the fruits also limits the manufacturing area of these fruits.

Shade Tolerance and Windbreak Protection

Pumpkins, squashes, and marrows tolerate partial shade and so may be grown among corn plants. A good plan is to sow a row of the vine crop and line it on both sides with 3–4 rows of corn. The corn acts as a windbreak to prevent the vines from blowing about, and as soon as they begin to run it actually holds the plants in place. But the vine crop cannot compete successfully with tall woody plants for moisture and must not be set too close to them.

Harvesting

Summer types are gathered before the seeds ripen or the rinds harden. They are used while young and tender (two-thirds, or so, full grown) and easily penetrated by the thumbnail. The winter types will not keep unless they are well matured. They are harvested when fully ripe. They will stand some frost but not a severe freeze. They may be left in the field for a time to harden if piled up and covered at night. The fruit is usually cut off the vine with a bit of the stem attached. Pumpkin and squash often yield more than 10 tons per acre.

Storage

A gradual decline of the storage temperature to 45–50°F., as the winter season approaches, and relative humidities below 75 percent are best for squash.[148]

Pumpkins do not store as long as the usual storage varieties of squash and seldom remain in good condition more than 2–3 months. Blue Hubbard squash stored 3 months is sweeter and more moist than that canned after 2 weeks' storage. It is also sweeter than that canned after 6 months' storage, and the color is brighter than squash stored only 2 weeks. Therefore, before processing, squash should be stored for a time first. Pumpkins freeze at 30.1°F., and winter squash at 29.3°F.

Insect and Disease Control

Squash vine borer wasp-like moths lay oval, dull-red eggs on the stems of the vines. The white larva bores into the main stem, causing the leaves to wilt and the vines suddenly to die. If only a few vines are attacked, the borers can be removed by slitting the stem at the point where they are working. The stem is then covered with earth for a short distance beyond the slit portion. Dusting the stems with sabadilla or rotenone checks serious outbreaks.

Squash bugs are large, brownish bugs with a disagreeable odor ("stink bugs"). They emerge from under rubbish or other shelter in late spring. They become full grown in late summer, but immature forms may be found later. They suck the plant juices and cause wilting and browning of the leaves or of entire vines. Dust with sabadilla or rotenone.

Angular leaf spot on the leaves of summer squash is first watersoaked, later tan to chalky and angular, and then dries out and drops. Small, watersoaked spots occur on the fruits, often followed by a soft rot. Controls are rotation, sanitation, seed treatment (see Table 5), and dusting alternately with a carbamate or fixed copper when the vines begin to run and then weekly.

Other diseases controlled by a combination fungicide and insecticide are wilt, downy mildew, and anthracnose. Paper plant protectors temporarily circumvent the insects that carry wilt bacteria and mosaic virus. (See also Cucumber.)

CUCUMBER

"Cool as a cucumber" is a common expression. The fruits are usually eaten sliced and raw or as pickles.

History

The cucumber originated in India. Sir Flinders Petrie, an Egyptologist, found the remains of the cucumber in tombs of about 2300 B.C., and so established the species as one of the most ancient cultivated by man. In the Caucasus region there are names for the cucumber that predate Sanskrit. Columbus grew the crop in 1494 on the island of Haiti.

Most modern varieties have gradually evolved from the European sorts brought to this continent by the early settlers. Joseph Tailby, Wellesley, Mass., who exhibited Tailby Hybrid in 1872, was one of the first to cross the "Spine" and English forcing types.

Early Cluster, Early Frame, Early Russian, Long Green, and White Spine were listed in the earliest seed catalogs. Arlington White Spine, Everbearing, Cool and Crisp, Everbearing White Spine, Henderson Perfected, Chicago Pickling, and Boston Pickling were developed before 1900, and Davis Perfect, Early Fortune, and Snow Pickling in the period 1900–1910. Later ones are: 1924, National Pickling; 1928, President, A & C (Abbott and Cobb); 1933, Clark Special; 1934, Barteldes; 1935, Straight 8, Colorado; 1937, Mincu; 1943, Marketer; 1944, Cubit; 1945, Burpee Hybrid; 1947, Packer, Model, Producer; 1948, Palmetto, Puerto Rico 39, Magnolia; 1949, Highmoor; 1950, Yorkstate, Surecrop, New York, Santee.

Varieties

Field-Grown Slicing Type

The fruits of field-grown table varieties average about 8 inches long, retain their green color well, and mostly are white spined. While the fruits are small they may be used for pickles, though the pickling type is usually grown for this purpose. Leading varieties are: *Clark Special,* A & C (*Barteldes, Deltus, Colorado*), *Black Diamond* (*Stays Green*), *President, Windermoor Wonder* (*Vaughn, Longfellow*), *Marketer, Cubit,* and *Burpee Hybrid. Surecrop* (All-America, 1951) shows resistance to mosaic and downy mildew. *Niagara* shows resistance to mosaic. For the South, *Palmetto* and *Puerto Rico 39* are highly resistant to downy mildew. *Santee* is moderately resistant to downy mildew and angular leaf spot, and is high yielding in the South.

Pickling Type

Most pickling types are smaller than the slicers, less tapered at the tip in immature stages, and more productive of small fruits; they shrivel little or not at all in pickling. When the fruits become larger than pickling sizes they may be used for slicing, but other kinds are better for this purpose.

The older pickling varieties, such as *Boston Pickling, Chicago Pickling,* and *National Pickling,* are black spined. *Model* and *Producer* are white-spined newer varieties. *Yorkstate* is mosaic resistant; *Magnolia* is liked in the South. *Early Russian* and *Mincu* are adapted to short-season regions.

Forcing or Greenhouse Crop

The greenhouse group includes the long English types, e.g., *Telegraph,* that are commonly parthenocarpic. The English type is not popular in America. Varieties such as *Davis Perfect* might properly be termed an intermediate class as they are crosses of the English and field types. Hybrids are becoming popular for greenhouse culture.

Novelty Group

Snake is an ornamental curiosity that is not a true cucumber; the fruit is 2–3 feet long, coiled and twisted snake-like, and never grows straight unless suspended. Both *China Long* and *Chinese Three Feet* differ noticeably in both fruit and foliage from the true cucumber and have long fruits. *Japanese White* runners keep their tips raised from the ground like squash vines; the vines develop strong grasping tendrils which enable them to climb wire netting or other supports. Other whitish varieties are *Lemon, Crystal Apple,* and *White Wonder.*

For the backyard gardener with little space there is a bush or dwarf type, e.g., *Midget,* which possesses some merit for pickling or small slicing.

West India Gherkin is not a true cucumber and has little if any commercial value. The term "gherkin" is commonly used for small fruits of the usual pickling cucumbers. *African Horn* is a novelty of no particular value.

Producing Cucumbers

Climate

The cucumber is a warm-season crop that is easily injured by frost, but it needs only a relatively short season to produce its fruits. It tolerates slightly cooler weather in the fall than melons. The seed does not germinate unless the soil temperature

is above 50°F. A cold, wet, early summer commonly results in a poor crop. Shelter from strong wind is advantageous.

Pollination (see also Chapter 1)

The pointed-end type of cucumber is favored in South Carolina.[15] When round or blunt-ended fruits, e.g., Cubit, are not pollinated properly they grow with a constriction about 2 inches from the stem end. This is caused by normal growth at the large seed-free space at the stem end and abnormal development of the seed cavity. Low-grade fruit or a cull results. When a pointed-end variety, e.g., Marketer, is not properly fertilized the point on the end is elongated but there is no constriction such as in Cubit. Such a type will grade higher and produce fewer culls and low-grade fruits. Another merit of the pointed-end fruit is that it packs and ships better in bushel tubs.

Also, a correlation exists between the blunt-ended fruits and the expression of the placental hollow character. The appearance of these hollow spaces in the placental tissues 2–3 inches from the stem end is a genetical character found in Cubit, Palmetto, and several other varieties. Its appearance and severity is not only influenced by genetics and weather conditions but also by the shape of the fruit. Pointed-end fruits are far less subject to it.

Many persons, however, think that the round-ended character is desirable and that this shape should not be held against some of the newer kinds such as Sensation, Surecrop, Burpee Hybrid, and Niagara.

Soil, Manure, and Fertilizer

None but the best land can be depended upon to give good yields of well-formed cucumbers. Sandy or sandy loam soils promote early crops; silt or clay loams are preferable where heavy later yields are wanted. A soil that tends to crust or become hard and tight and lacks humus should be avoided.

Though the cucumber is not a very heavy feeder, fertile soil with plenty of humus encourages a high yield. The cucumber should make a continuous, steady growth. In a rotation, cucumbers should not follow such heavy feeders as sugar beets or cabbage, unless the land is naturally fertile or has been liberally manured or fertilized. A higher level of nitrogen nutrition seems

necessary for a high yield of well-shaped, well-colored cucumbers than is needed for pumpkin, squash, and vegetable marrow. Some of the nitrogen may be applied as a sidedressing.

In a 12-year test the Ohio Experiment Station obtained an increase of 82 percent in yield from 16 tons of manure and 21 percent from 1,220 pounds of 4-10-4 fertilizer, as compared with no fertilizer. In Michigan, it is advised that 10–15 tons of manure plus 300 pounds of superphosphate be broadcast in early spring before plowing.

In Mississippi,[5] good yields were obtained with pickling cucumbers from 800 pounds per acre of 6-8-8 or 8-8-8 fertilizer. Many more No. 1's were made by the fertilizers having more than 2 percent nitrogen when the phosphorus and potash were each 8 percent. Four percent phosphorus was too low, but more than 8 percent did not seem justified. In the potash series nearly 500 pounds of No. 1's were made by the first 4 percent increment in potash; higher proportions made little difference in yield.

Systems of Seeding and Spacing

Since the plant is tender and the seeds will not germinate in a cold soil, seeding is delayed until danger of frost is over. An excess of seed commonly is sown to ensure a stand.

Hill system. Hills are spaced 4 × 5, 5 × 5, or 3 × 6, depending on soil fertility and growing conditions; 5–7 seeds are sown per hill. The seeds for each hill are sown at moist-soil depth over a flat area, 6–10 inches in diameter, made with a hoe. When the plants come up, they are thinned first to about 4–5 and later, after danger of loss from cucumber beetles is largely over, to 2–3 per hill. Hill plantings can be cross-cultivated in early stages of growth, and this system facilitates picking.

Drill system. In large plantings, seed is drilled thinly and continuously in rows 3–6 feet apart, averaging about 2–4 pounds per acre. Later, the plants are thinned to 12–18 inches apart in the row. Plants sown in drill rows, particularly when the rows are comparatively close, are not damaged by whipping by strong winds as much as those in hills, because the plants form into a thick mat. When the plants are 18 inches long the tips of the main stem sometimes are removed to induce branching; if this results in more fruits it promotes lateness.

Irrigation

Irrigation plays little part in growing cucumbers, even though the fruit is about 95 percent water. In most years it is not necessary to irrigate at all, but it is wise to apply water if the plants begin to show effects of drought. Cucumbers are less likely to suffer from drought on a heavy soil than on a sandy one. It is seldom necessary to irrigate more than once or twice during the year. The chief demand for water is usually in midsummer. It is unwise to irrigate after cucumbers are market size.

Cucumber rows are usually spaced farther apart than rows of most vegetables. Hence a shallow furrow can be made on either side of the row of cucumbers or 2 shallow furrows between every 2 rows. The water is run long enough to soak the soil well. It must not overflow and touch the plants, because if they stand in water for any length of time the foliage becomes chlorotic or yellow and growth is checked.

Cultivation

The plant is shallow rooted. Shallow cultivation should be repeated often enough while the plants are small to close soil cracks and control weeds. Hand hoeing and pulling large weeds by hand may be needed after the plants begin to vine.

Frame Culture

Seeds are sown directly in hotbeds or coldframes. When the weather gets warm, the sashes are removed. Frame culture permits lengthening the season at both ends.

Harvesting

The vines begin to bloom 4–6 weeks from seeding and produce small pickles in 6–7 weeks or in late summer. The season extends until frost kills the vines. The first 2–3 pickings hardly pay for the labor involved, but if large cucumbers are allowed to develop, much of the strength of the plant goes into ripening the fruits instead of forming more of them.

Daily harvesting is likely to be needed at the peak of the season with pickling types, but ordinarily 48–72 hours occur between harvests of slicing types. Cucumbers are picked by hand,

care being taken to avoid injuring the vines. A short piece of stem is left on the fruit. Very small sizes, straight and uniform, are preferred for whole pickles. Those up to 5½ inches are in demand for dills. For slicers, straight, dark-green, smooth, uniform fruits 6–10 inches long are desirable. A good yield is 100–150 bushels per acre of market cucumbers, or 75–100 bushels of picklers.

Waxing

Waxing of slicing-type cucumbers reduces the rate of shrinkage and shriveling and improves the appearance. Waxed fruits keep their dark-green color longer. Also, the wax film tends to reduce pitting of greenhouse-grown fruits marketed in cold weather.

Storage

Cucumbers can be stored for about 10–14 days at 45–50°F. and 85 percent relative humidity. Below 45°F., dark, watery areas appear, and soon become infected with mold. At 50°F., little breakdown develops for some time, but the fruits tend to change from green to yellow. The average freezing point is 30.5°F.

Insect and Disease Control

Cucumber beetles are small, black and yellow, and striped or spotted. The adults winter under trash or in the soil. Egg laying starts in early summer. The broods overlap so that the beetles are present all summer. Besides damaging the plants, the beetles carry mosaic and blight. Dusting young plants frequently with rotenone is fairly effective.

Anthracnose affected leaves develop dead circular spots. These spots may be so numerous that the whole leaf is destroyed. On the stems, elongated light-brown areas may occur. Controls are: treating the seed (see Table 5), and spraying or dusting with a carbamate or fixed copper.

Scab watersoaked spots appear on the leaves and stems. Sunken spots on the fruit become dark brown with a viscid, gummy exudate. The canker grows larger and deeper, becoming lined with a dark-green, velvety layer of threads. Controls are: treating seed in 1-1,000 corrosive sublimate for 5–10 minutes;

dusting with a fixed copper; plowing under the vines after harvest; a long rotation; and destroying plant refuse.

Downy mildew resistant varieties are Puerto Rico 39, Palmetto, and Burpee Hybrid.

Fusarium wilt causes wilting of the growing tips followed by yellowing and death of the entire plant. If the lower part of the stem or root is cut across, the conducting tissues (vascular bundles) are usually brown and discolored. Controls are: removing and burning all affected plants, and not planting vine crops on the same soil for several years.

Bacterial wilt causes a whitish, sticky slime to ooze from the ends of the stem if it is cut; if allowed to dry for a few minutes this slime will string out when touched. Controls are: dusting to kill the cucumber beetles which spread the disease, and destroying affected plants.

Mosaic plants show yellow and green mottling of the leaves. Fruit does not set properly. Controls are: destroying host plants, such as wild cucumber, ground cherry, and milkweed; dusting to kill aphids and cucumber beetles; roguing when only a few plants are affected; and planting resistant varieties like Producer and Burpee Hybrid.

Angular leaf spot has been discussed earlier.

MELONS

Melons (a general term that includes the cantaloupe, honeydew, muskmelon, and certain other types) need abundant room and are usually grown as a specialty crop in fields, seldom in small gardens.

Melons need a long frost-free period. The foliage is easily damaged by late-spring or early-fall frosts. Rapid growth is made in midsummer and late summer, when the days and nights are warm, but the fruits ripen very slowly when the nights become cool. A dry atmosphere during the ripening period together with appropriate sunshine and temperature conditions result in high sugar content. If the weather is cloudy or rainy during the ripening period, melons are often insipid.

Probably no fruit offered to the public is so appealing and tasty when properly presented; but probably no fruit is so unappetizing when improperly presented. Herrara, a Spanish

writer, in 1513 said: "If the melon is good, it is the best fruit that exists, and none other is preferable to it. If it is bad, it is a bad thing."

History

The melon is native to the hot valleys of Iran (Persia) and northwest India. Columbus brought the melon to America. In

Fig. 71. Cantaloupes of high quality are produced in British Columbia. *(Courtesy W. H. Robertson, British Columbia Department of Agriculture.)*

McMahon's 1806 catalog, 13 sorts were listed, all from the Old World. Of these, Citron (Green Fleshed Melon) and Nutmeg were the foundation for many subsequent green-fleshed melons.

Orange-fleshed sorts were grown in McMahon's time. Long Yellow was known about 1846. Highly colored sorts soon became more prominent, e.g., Christianism about 1850, Sill Hybrid in 1870, and Surprise in 1876. An orange-fleshed importation (White Japan) after Perry's visit to Japan in 1853 may have contributed to Surprise and others of its type.

Seedsmen showed little interest in selection until after 1880. During 1880–1890, 17 new sorts were cataloged, among them

Irondequoit, Miller Cream, Netted Gem, Hackensack, and Osage. In the next decade, about 30 varieties appeared, e.g., Bender, Paul Rose, and Tip Top. The first 20 years of the twentieth century saw the development of Defender, Fordhook, Knight, Pollock, Hearts of Gold, and Melodew. In the next 15 years at least 27 new varieties were introduced, e.g., Delicious, Golden Champlain, and Hale's Best. All-America awards were made to Honey Rock and Improved Perfecto in 1933, Imperial in 1935, Queen of Colorado and Wayside Market in 1939, and Honey Gold in 1941.

The Rocky Ford district of Colorado is the birthplace of the American cantaloupe industry. In 1881, Netted Gem was introduced there; carlots were shipped in 1896. Early Watters followed and was important until about 1912. In 1904 work was begun by the Colorado Experiment Station to develop a rust-resistant strain. One developed by J. P. Pollock was named Rust Resistant Pollock; like its predecessors, it was green fleshed. Then Salmon Tint Pollock 25 became the leader until Salmon Tint Pollock 10-25 was introduced in 1919. This gave way to the Hale's Best type in 1924.

In California, in 1925, Dr. I. C. Jagger, U. S. Department of Agriculture, and Dr. J. T. Rosa, and, later, Dr. G. W. Scott, University of California, undertook the development of mildew-resistant melons. Resistance was discovered in types from India, and over a 9-year period 8,000 individuals were tested. As a result, Mildew Resistant 45 appeared, and it saved the Imperial Valley cantaloupe industry. Mildew Resistant 5 and 6 are resistant to both race 1 and race 2 of powdery mildew.

Classification and Varieties

A. Banana group. Fruit banana shaped, 12–18 inches long, 4–5 inches across; flesh light salmon; banana-like flavor; late: Banana.

B. Jenny Lind group. Fruit small, flat, base and apex flattened and full; blossom scar conspicuous, often has a prominent knob.
1. Green flesh: Jenny Lind.
2. Pink flesh: Fordhook.
3. Salmon Yellow: Emerald Gem.

C. Defender group. Fruit oblong, medium to large, ribbing irregular, netting moderate to absent; flesh salmon tinted; grown for home garden and local market: Burrell Gem, Osage (Miller Cream), Ohio Sugar, Golden Delicious, Delicious, Extra Early Osage.

D. *Hoodoo group.* Fruit moderately small, slightly elongated and nearly globular, heavily netted, moderately to finely laced; skin dark green; flesh pink: Paul Rose, Hearts of Gold (Hoodoo Improved).

E. *Early Ripe group.* Notably early, medium size; flesh golden-yellow, ribs fairly prominent; not quite as early as the Earliest type (see group *N*) but superior in other respects: Lake Champlain, Golden Champlain, Chipman Champlain, Farnorth.

F. *Surprise group.* Fruit moderately large, oval to nearly globular; netting sparse or medium, patchy, often streaked to evenly netted; skin light creamy yellow; cavity rather large; flesh salmon; medium early: Surprise, Bender Surprise, Irondequoit, Tip Top, Iroquois, Aristocrat, Oregon Delicious, Golden Marvel, Oka, Schoons Hard Shell, Perfect.

G. *Honey Rock group.* Fruit round to almost round, medium size; flesh pink with a tough, hard rind; netting distinctive, coarse, heavier than that on most melons; midseason: Honey Rock (Sugar Rock), Granite State.

H. *Netted Gem group.* Fruit small, short oval, ribbed and well netted; sutures not netted over; flesh green, and in certain cases such as Knight the flesh blends from a light green to a salmon pink adjacent to the cavity; early; progenitor of Rocky Ford group: Early Watters, Bottomly, Early Imperial, Knight.

I. *Rocky Ford (Pollock) and Perfecto group.* Fruit small to medium, rounded oval, not ribbed, heavily netted; sutures absent or shallow and well netted over; medium early to late in the case of the Perfecto type.

1. Green flesh: Gold-lined Rocky Ford, Eden Gem, Green-Meated Pollock, Netted Rock, Mission Bell.
2. Pink flesh: Golden Pollock, Rice Orange Fleshed, Perfecto, Superfecto, AZ, Perfected Perfecto.
3. Pink around cavity: Salmon Tint, Pollock 10-25, Gold-Lined Pollock, 101 Special.

J. *Hale's Best group.* Fruit globular, small to medium, moderately ribbed, distinctly netted; seed cavity small to medium; flesh orange, medium to thick; midseason: Hale's Best, H.B. 36, Powdery Mildew Resistant 45, H.B. Seed Breeders, Winner, Purdue 44, Texas Resistant No. 1, Mildew Resistant D-2, Jumbo Hale's Best, Early May, Golden Gopher, New Ideal.

K. *Hackensack group.* Fruit large, flat; ribs prominent; netting heavy, coarse; sutures smooth, medium deep; midseason.

1. Green flesh: Large Hackensack, Montreal Market, Milwaukee Market, Baltimore Market, Extra Early Hackensack, Long Island Beauty.
2. Pink flesh: Greely Wonder, Indiana.

L. *Weaver group.* Fruit round; skin white, flesh orange; noted for fine flavor and smooth flesh: Weaver Special, Golden Delight, Golden Globe, Pride of Wisconsin (Market King, Pride of Colorado).

M. *Winter types.* Very late; requires a very long growing season.

1. *Honey Dew group.* White exterior color, ripening to a light cream; not netted; flesh green: Honey Dew, Honey Ball, Powdery Mildew Resistant Honeydew No. 60, Golden Honeymoon (Golden Rind Honey Dew).

2. *Persian group.* Large, nearly globular (7–10 inches), without ribs, profusely and uniformly covered with a light, moderately broad netting; flesh very thick, pink, fine textured: of chief importance in the hot valleys of southern and central California and in Arizona: Persian, Baby Persian, Turkish, Oro Blanco.
3. *Casaba group.* Fruit large, oblate-oval, or short pyriform in shape, lemon-yellow in skin color, tough skinned, not netted or ribbed, but profusely marked with longitudinal corrugations or deep wrinkles; flesh very thick, nearly white, juicy, without aroma, sweet, and of good quality when properly ripened; suitable for culture only in parts of California and the Southwest: Golden Beauty, Golden Hybrid, Crenshaw.

N. Earliest type. Of exceptionally early maturity; fruit small, soft: Edible Gold, Arctic Sweets, Northern Honeysweet, Zephyr.

Features of *Hale's Best* (and its type) are earliness, well-netted fruits, thick, firm, deep-golden-colored flesh, ability to maintain fine quality even into the overripe stage, and good shipping quality. *H. B. Seed Breeders* and *H. B. 36* are more uniform than the original. *H. B. 112* is round, *H. B. 936* is long, and *H. B. 45* is resistant to powdery mildew. Some leading varieties for nearby markets are: *Bender Surprise, Iroquois, Osage, Tip Top, Burrell's Gem, Knight, Paul Rose, Lake Champlain,* and *Hackensack. Granite State* (All-America, 1951) is very early. *Honey Dew, Honey Ball,* and *Persian* are grown in California and Arizona but not in the East.

Fruiting Habit and Pollination

Melons differ from squash and cucumber in being andromonoecious (staminate and hermaphroditic flowers on the same plant). Though the complete flowers are self-fertile, the flower structure and stickiness of the pollen are such that much cross-pollination occurs by means of bees. About 5–15 percent of the seed of the hermaphroditic varieties may be cross-fertilized if different varieties are grown in adjoining rows. Hence it would seem that bees tend to move along the row, rather than doing much crossing over from one row to another. In Texas,[193] self-pollination or inbreeding within certain fruits reached 100 percent even with opportunity for cross-pollination, and the extent of selfing among the seed samples varied from 0 to 100 percent. Out of 21 single-fruit-derived lines 8 had all the plants

of selfed origin, 5 lines had fruits of hybrid nature, and the remaining 8 lines had fruits of mixed origin varying from 16 to 97 percent of inbred fruits.

The female or hermaphoditic flowers, which determine the location of the fruit, form in the first 2 leaf-axils of the fruiting branches and also occasionally on the laterals. After 1–2 develop on a stem, the ovaries of all flowers formed on the next 8–10 fruiting branches of that stem will abort. Then may ensue a second setting period, wherein 1–2 fruits may form, followed by a second sterile period. During the nonsetting periods, the development of the fruiting branches is reduced.

Melons cannot be crossed with cucumbers, watermelons, pumpkins, or squashes. Therefore poor quality in melons cannot result from foreign pollen.

Producing Melons

Soil

A light soil, such as a sandy loam, and one with a gentle south or southeast slope, results in early melons. Melons need a warm soil so that their growth will be rapid. Muck or peat is not suitable. Melons are not so sensitive to drought as some other cucurbits. They will not endure an area subject to overflow or soils on which water stands in furrows after a rain.

The soil should be finely prepared before seeding and should be plowed 8–10 inches deep early enough so that it can settle well. The comparatively late date of seeding usually makes spring plowing as suitable as fall plowing except with heavy soils. The plant thrives best at *p*H 5.8–7.2. On highly acid soils, the leaves turn yellowish and die at the edges, especially in dry years, possibly because of unavailability of some nutrient in the soil.

Fertilizer

Soil-improving crops or other means should be used to supply organic matter. Manure, if well decomposed, can be applied heavily. Applying ground limestone to acid soils often increases the yield; the stems and leaves of cucurbits are high in calcium. Melon fruits and seeds remove much nitrogen and potash, and

when the crop is grown on soil deficient in these elements they should be added.

Seeding

Under favorable conditions melon seed germinates about 2 days after sowing. A "peg" develops which helps to remove the seed coats as the cotyledons push up through the soil. Germination does not occur below 50°F., and so seeding is delayed until the soil is warmer. Sowing too early usually results in poor stands and stunted plants, hence a crop no earlier than one sown at the proper time. Seeding is delayed also so that germination does not occur until frost is over. The earliest sowings are made in November and December in southern California, in February in south Texas and Florida; the dates become later as the season moves northward, with the final seedings made in late May and early June in northern areas.

Transplanting. The melon is difficult to transplant successfully except when very young and will not thrive well if the root system is much disturbed. The roots develop a suberized layer at an early age, so that they are ineffective for direct absorption of water and formation of new roots is retarded.

Suberin consists of a cellulose chemically combined with compounds of a fatty or wax-like nature which makes the cell walls of the roots impervious to water. Three groups, based on the suberin condition, can be arranged.

1. This group includes plants of cabbage, lettuce, and tomato, which easily survive transplanting. New roots are formed quickly and a significantly small amount of suberin is present in the roots, thus permitting an efficient absorption of water.

2. During the first few days after transplanting the young plants of celery, onion, and pepper do not produce new roots quickly. They are moderately easily transplanted. The suberin content in the roots of these plants is greater than in the roots of the plants of the previous group.

3. Subsequent to transplanting, melon plants produce in the same time of growth a smaller amount of roots than do the young plants of the two previous groups. They do not grow well with the ordinary method of transplanting. Their roots possess more suberin and hence absorb less water. Certain procedures help to avoid this damage and give, on a small scale, very early melons.

Seed for transplanting is sown under glass 3–4 weeks before the time for field seeding, in 3–4 inch wood veneer bands, paper boxes, clay pots, jam cans with holes in the bottom, or squares

of inverted sod. Several seeds are sown in each receptacle, and the plants are thinned to 1–2 when they are well established. The plants, when they have about 4 rough leaves, are transplanted to the field in "hills" prepared for that purpose, care being taken not to disturb the roots.

Transplanting enables good control of temperature and moisture during early stages of growth, protection against insects (e.g., striped cucumber beetle) during critical stages, and earlier maturity. Drawbacks are the cost, difficulties of transplanting, and reduced yields in most areas.

HILLS. The field is check-rowed, and the seed is sown at the intersections, with the aid of a hoe or a hand planter. The spacing in the rows, and between rows, is usually 4–6 feet. When 8–10 seeds are sown in a hill, 1 pound of seed is needed per acre. The seed is sown about 1–1½ inches deep in the drier regions and ½–1 inch deep in humid regions. The hill system saves some labor in cultivation.

DRILL ROWS. Seeds are dropped every 2–3 inches in the row with a drill or seeder, and 2–3 pounds are required per acre. Care is taken to get a uniform depth of not over 1½ inches. Drill-row seeding is quick.

"BUG ROWS." Seed may be sown thickly in extra or "bug rows" between the usual rows of melons. When the plants are weeded and thinned the bug rows are left untouched. The thickness of the plants and the added shade attract the bugs, which therefore do little damage to the rows of good melons. The bug rows are removed before bloom, and by this time the danger of bug damage is mostly past.

"BRUSHING." To protect the plants in early stages of growth, e.g., in southern California, brush (willow) is placed around the hill or down the row. This practice also conserves heat and raises the temperature around the plant.

MELONS IN FRAMES. In some areas, seed is sown in hotbeds or coldframes where the vines are to remain. This results in earlier yield, and in northern regions permits success with varieties that would otherwise be too late.

CULTIVATION

The root system of the melon plant is confined mostly to the upper 6–10 inches of soil. Cultivation should be shallow and

should cease after the vines are 1½–2 feet long. Hand hoeing may be needed after vining starts. Large weeds near hills should be cut instead of pulled.

"Laying out" the vines may enable cultivation to be continued after the vines have begun to run. They are turned to follow the row, to allow the cultivator to go between the rows, and, in irrigated sections, to keep the fruit out of the water furrows. Care is taken not to turn the vines upside down, for otherwise the heat of the sun may damage the newly set fruit. Moving the ends of the vine with a stick may be justified, but turning them from one row to the other may seriously injure them.

Thinning

When a true leaf has appeared between the seed leaves, the plants are thinned, if necessary, to 4 in a hill. A final thinning leaves 1–2 plant per hill or, in continuous row plantings, 1 plant every 2–3 feet in the row. Where cucumber beetles are especially troublesome the final thinning is usually delayed until the plants are well established and each has 3–4 true leaves. To avoid disturbance of the root system of the plants that remain, cutting the seedlings to be discarded is preferable to pulling them.

Nipping and Pruning [25]

Early American writers on melon culture gave detailed instructions for nipping the vines. Evidently this advice was based on European practices in growing the crop under glass or on very small areas. The theory was that nipping the main vine hastened formation of the laterals that bear the crown-setting or first fruits. Tests in Illinois and New Hampshire have shown that little if anything is to be gained by nipping or pruning melon vines grown outdoors, under ordinary conditions. Reducing the number of melons on a vine will increase the size to which the remaining melons can grow. But melon vines of most varieties produce some melons too large for a standard pack even without nipping or pruning; so these operations may bring about loss rather than gain.

Irrigation

Most soils used for melons are subject to drought because of their light texture. One thorough irrigation to wet the soil

deeply, to field capacity, before sowing the seed may be all that is needed to assure a good crop. Melons are deep rooted.

Harvesting

For highest quality, melons must ripen on the plant. Too many melons are marketed that show either lack of good judgment regarding proper degree of ripening or greediness of the grower to sell immature fruits; overripeness should be avoided. Some indices of maturity are: change in ground color; softening of the shell at the blossom end; color and degree of development in the netting; change of the color of the base of the pedicel from a green to waxy appearance; cracking about the stem; aroma; taste (tested by cutting an occasional fruit); and presence of the full-slip stage.

Melons that turn yellow on vines that have died or have been largely defoliated by disease are certain to be almost worthless even though they may appear to be of some value. In the watermelon, the color of the "ground spot," or the portion in contact with the soil, is helpful in determining maturity. In the melon, however, the under surface changes in color along with the entire surface area and does not show a definite "ground spot."

The right way to remove a melon from the vines is to press on the stem with the thumb, or slightly lift the fruit from the ground. If the melon is ripe enough to be picked the stem will separate from the fruit. At the "full-slip" stage, the ripe fruit slips easily from the stem, leaving a smooth cavity; at the "half-slip" stage, only part of the stem slips cleanly when the fruit is forced off. The slip does not develop in types such as Crenshaw, Honey Dew, and Casaba.

With modern methods of precooling and refrigeration the recently introduced strains of melons reach distant markets in good condition after ripening on the vines to the full-slip stage. In fact, many of them are not of desirable quality until a few days after the full-slip stage. Until about 1938 most melons had to be picked at half-slip for shipping, as they were best for eating when they reached the full-slip stage. Powdery Mildew Resistant No. 45 proved to be a good shipping type when picked at the full-slip stage, becoming of desirable quality 3–4 days later. Under refrigeration the lapse of time is even longer.

Western growers usually group melons into three maturity classes.[25] These are, in ascending order of ripeness, "fancy," "hard ripe," and "choice." The best melon for eastern shipment is the full-slip hard-ripe melon. Hard-ripe melons need prompt and adequate refrigeration if they are to be shipped distances requiring more than 2–3 days. Choice melons are full slip and yellowish. At transit temperatures of 40°F. or less, as provided by top icing, they can be shipped from California to eastern markets. Fancy melons, the least mature class harvested in the West, are half to full slip, greenish, and hard.

Melons should contain at least 10 percent sugar before shipping. Immature melons are lower in sugars than more mature ones. Melons gain in flavor, but not in sweetness, after being picked; fruits picked green never become sweet. The sugar is lowest at the stem end and higher toward the blossom end of the fruit, but no consistent differences between the ground half and the upper half of the melons exist. The sugar content of the juice of the placenta and that found in the seed cavity is usually between the extremes of that found in the flesh, but higher than the composite sample of juice. The sugar content of that portion of the flesh nearer the seed cavity is higher than that of the flesh nearer the rind, but this variation is not great in fully ripened fruits.

Most shoppers do not know how to recognize a ripe honeydew. Some suggestions follow: a ripe honeydew has a characteristic even, cream color; avoid a white honeydew or particularly one which is white with a greenish tinge to it; select a melon which has a soft to mellow feel to the rind; a ripe honeydew has a velvety rather than a hard exterior; pushing on the blossom end of a honeydew will bruise the melon without telling much about its maturity.

Containers

Western cantaloupe crates are designed to hold certain standardized packs of melons. The pony flat crate (4 × 12 × 22⅛ inches, inside) holds a pack of 15 or 18 melons; the standard flat (4½ × 13 × 22⅛), 9, 12, or 15 melons; jumbo flat (5 × 14½ × 22⅛), 8–12 melons; pony crate (11 × 11 × 22⅛), 45–54 melons; standard crate (12 × 12 × 22⅛) and the jumbo crate (13 × 13 ×

22⅛), 27, 36, or 45 melons. Two common sizes of western honeydew crates are: standard (6¾ × 16 × 22⅛), 9 or 12 melons; and jumbo crate (7¾ × 16 × 22⅛), 6 or 8 melons.

STORAGE

Melons ordinarily are not stored, but mature fruits keep best at 32°F. and 85–90 percent relative humidity. The flesh freezes at 29°F. and the rind at 28.4°F.

Insect and Disease Control

Melon aphid sucks juices from the plant, causing the leaves to become curled, distorted, and stunted. Control is to dust with nicotine.

Cucumber beetles are controlled as described under Cucumber.

Melon worm and *pickleworm* attack the foliage and buds and feed in the fruit. Their presence is shown by small holes, usually on the underside of the fruit. Controls are to dust, before fruits form, with cryolite, and after fruits form, with rotenone.

Iroquois melon is resistant to *Fusarium wilt. Powdery mildew* resistant varieties have been mentioned earlier. Rio-Sweet, developed in Texas, is resistant to downy mildew. For *damping-off*, see Index.

Anthracnose, bacterial wilt, leaf spot are discussed under Cucumber.

Mosaic results in leaves mottled with greenish yellow, stunted plants, and fruit of poor quality. East of the Mississippi, mosaic generally is caused by the cucumber mosaic virus that is not carried in seed. Other forms of virus that are seed borne attack melons in the West. None of the viruses are carried in soil. They live over in perennial weeds (which should be destroyed) and are carried from weeds to cultivated crops by plant lice. If mosaic appears in young melons they should be destroyed.

WATERMELON

The watermelon is an important crop in the South. It is used mainly as a dessert. Shipments from southern Florida and southern Texas begin in April, and the harvest season gradually moves northward. In the most northern of the watermelon producing

States the crop is harvested about October 1. When the northern crop is gone, California and Colorado continue to supply special varieties which are available in limited supply until Christmas.

History

The watermelon had a name in Sanskrit and so is known to have been in cultivation a long time. It is native to tropical Africa. In 1857, Livingstone reported both edible sweet and inedible bitter forms of it growing profusely in the Kalahari Desert after an unusually heavy rainfall. The natives made long journeys to obtain sweet ones.

Except Bradford (Alabama Sweet), no variety mentioned prior to 1850 is listed today. The leading modern shipping varieties are fairly recent developments, but three local-market melons still listed by dealers are 75 years or so old. Peerless (Ice Cream) was introduced in 1860, and Phinney Early and Georgia Rattlesnake about 1870.

Many varieties listed today were introduced between 1880 and 1900, e.g., Cuban Queen, Round Light Icing, Kolb Gem, Hungarian Honey, Florida Favorite, Dark Icing, Monarch, Cole Early, and Kleckley Sweet. Tom Watson, long the dominant shipping melon, originated in Georgia and was introduced in 1906. Irish Gray ranked second in the East in the early 1920's. It yielded its place to Thurmond Gray, which first became prominent in Georgia in 1923, and this in turn to disease-resistant varieties.

Classification (Red Fleshed) and Varieties

A. *Rind ivory with conspicuous green stripes.*
   1. Fruit cylindrical.
      (*a*) Seed white: Garrison (Darlington, Coker).
      (*b*) Seed white with colored tips: Georgia Rattlesnake (Gypsy).
      (*c*) Seed white with brown on sides: Dude Creek.
      (*d*) Seed mixed white and black: Striped Klondike.
      (*e*) Seed light tan with darker tan on sides: Congo.
   2. Fruit round.
      (*a*) Seed black: Cole Early (Harris Earliest).

B. *Rind dark green or bluish.*
   1. Seed white.
      (*a*) Fruit cylindrical.

(i) Rind thin, bluish green: Wondermelon (Improved Kleckley Sweet, Blue Wonder), Black Kleckley.

(ii) Rind tough, dark green: Leesburg, Pride of Iowa.

(*b*) Fruit round or oval: Angelina White Seeded, Miles.

2. Seed white, mottled brown; fruit round: Fordhook Early, Kleckley Sweet.
3. Seed white, tipped black.
   (*a*) Fruit cylindrical: Halbert Honey.
   (*b*) Fruit round: Stone Mountain (Dixie Belle).
4. Seed white, rimmed black; fruit oval round: Mountain Hoosier.
5. Seed brown.
   (*a*) Fruit cylindrical or oblong: Tom Watson, Blue Watson, Brown Seeded Klondike, Schochler.
   (*b*) Fruit round or oval: Early Arizona, Northern Sweet.
6. Seed tan to black: Klondike R7.
7. Seed black.
   (*a*) Fruit cylindrical or oblong; Winona, Blacklee, Excel.
   (*b*) Fruit round or oval: Cannon Ball (Florida Giant, Black Diamond, Texas Giant), Angelica Black Seeded, Kolb Gem.

C. *Rind gray.*

1. Seed white.
   (*a*) Fruit cylindrical or oblong: Irish Gray, Long Light Icing (Gray Monarch).
   (*b*) Fruit round or oval: Graystone.
2. Seed brown.
   (*a*) Fruit cylindrical or oblong: Thurmond Gray, Burrell Gray, Owen Gray (Arnell Gray, Arnold Gray, Gray Jacket).
   (*b*) Fruit round or oval: Early Canada.
3. Seed brownish black; fruit long, tapered at both ends: Hawkesbury (Gray Shipper).

D. *Rind bright green or pale green with darker green stripes or mottling.*

1. Seed white.
   (*a*) Fruit cylindrical or oblong: Florida Favorite.
   (*b*) Fruit round or oval.
      (i) Seed small: Chilean White Seeded, Dixie Queen.
      (ii) Seed medium size: Nancy Hanks, Peerless (Ice Cream), Round Light Icing.
2. Seed white, mottled brown; fruit cylindrical: Bradford (Alabama Sweet).
3. Seed white, tipped tan, very small; fruit round: Missouri Queen.
4. Seed black; fruit round or oval.
   (i) Fruit very small: White Mountain, Midget, Merrimac Wonder.
   (ii) Fruit small (15 pounds): Chilean Black Seeded, Winter King or Queen.
   (iii) Fruit medium weight (20–30 pounds): Sweetheart.
   (iv) Fruit heavy (35–45 pounds): Georgia Sweetheart.

5. Seed black, tipped white; fruit oblong: Phinney Early.
6. Seed brown; fruit round to oval: Dixie Queen Hybrid.
7. Seed bright maroon when immature, changing to buff when dry: fruit round: Early Kansas (Kansas Queen, Russian Red Seeded, Indiana Striped).
8. Seed gray; fruit round: Gray Seeded King or Queen (Christmas).

Some leading shipping varieties are *Tom Watson, Thurmond Gray, Cannon Ball, Georgia Rattlesnake, Dixie Queen, Irish Gray, Stone Mountain* (Dixie Belle), *Excel,* and *Blacklee. Garrison* (Darlington, Coker) is outstanding in quality for local use (see Harvesting). *Kleckley Sweet* is noted for home use and local marketing.

Missouri Queen (1947) and *Miles* (1949) are promising wilt-resistant types. *Congo* (All-America, 1950) is highly resistant to anthracnose.

In northern regions, the earliest varieties include *Early Canada, Sweet Sensation, Northern Sweet, White Mountain,* and *Sweet Siberian.* Some yellow-fleshed types are *Golden Honey* (Golden Sweet), *Hungarian Honey* (Baby Delight), *Honey Cream, Northern Sweet, Tendersweet* (Bankhead, Long Luscious Golden Honey). *New Hampshire Midget* (All-America, 1951) is a very small, oval, very early maturing "ice-box" melon of particular value in the short-season northern districts. *Northland* is another small, early type.

Chilean was introduced from the west coast of South America to California about 1900. *Angelina* and *Klondike* also appeared about 1900. The California Experiment Station has effected improvement in uniformity, flesh color, quality, and shape of certain varieties through careful selection in inbred lines. *California Klondike* was introduced in 1933, *Striped Klondike* in 1936, and *Long Mountain* (from Stone Mountain) in 1936. More recently, *Blue Ribbon* (from Striped Klondike) and *Klondike R7* have become widely grown in California.

Plant Characteristics

The stems are long running. The leaves are deeply divided into 3–4 pairs of lobes which are in turn lobed. The greenish yellow, tube-like flower is smaller than in *Cucumis.* There are

two general types: (*a*) hermaphroditic and staminate and (*b*) pistilate and staminate (monoecious). The fruit-producing flowers occur about every seventh axil, the intervening ones being staminate. Pollination is done by insects, chiefly bees, on the same day that the short-lived flowers open.

Unlike the muskmelon and squash where most of the edible portion is derived from the pericarp or rind, the edible flesh of the watermelon is mostly derived from the placentae. There is no true cavity in the watermelon. Ripe fruits contain 5–7 percent sugar, about half of which is glucose.

Producing Watermelons

Climate

The watermelon is tender to frost and needs a long growing season with high temperatures. As the watermelon is a warm-weather crop, it is useless to seed outdoors too soon in an attempt to promote earliness.

Freezing results in immediate death of plants, but temperatures below 40°F. which do not kill can cause severe damage by stunting young plants so much that further growth is slow. Frosted plants turn yellow, often with the tips and margins of the cotyledons browned and shriveled. But this browning is of a lighter color than that caused by the attacks of fungi. The older leaves, which are even more sensitive than the cotyledons, assume a bronzed, glazed appearance, particularly on the higher portions of the leaf surface, when subjected to very cool weather, and feel hard and brittle. Plants or leaves showing cold injury are susceptible to the attacks of various fungi and often are killed by them.

Strong winds often whip and tear the leaves severely. Such leaves dry out on the torn edges, become hard and brittle, and are susceptible to the attacks of fungi. Wind, during fruit setting, may whip off blossoms and young melons. High wind, during dry weather, often causes sand burn, which is characterized by almost white, rough, and brittle areas on the leaves and stems. Wind-blown sand injures the epidermis and cortex of the main stems and runners, causing the formation of thick callus over the injured areas.

Soil, Manure, and Fertilizer

A light sandy loam is usually best for watermelons. New land is often preferable because there is less likelihood of disease contamination, and the presence of a certain amount of litter and broken roots (unless it seriously interferes with cultivation) provides anchorage for the vines and avoids wind disturbances which may cause shedding of the young fruit. Also, the soil of recently deforested land contains much decayed vegetable matter, and plants growing on it withstand dry weather better than those growing on land that has been cropped for several years. The wilt organism may remain in the soil for 15 years. Where root-knot is involved, watermelons should not occur in a rotation oftener than once in 6 years. Some of the heaviest yields are produced on the sandy river-bottom or delta soils of southeastern Missouri and on similar soils elsewhere.

In Florida a *p*H of 5.5–6.0 is optimum on the acid sands. Marl soils and sands with a *p*H above 6.0 may need spray applications on the plants of 1½–2 pounds of manganese sulfate per 100 gallons of water where this deficiency develops.

The crops most commonly rotated with watermelons [26] in the South are corn and cowpeas, velvetbeans, cotton, winter oats, and peanuts; in the North they are corn, wheat, and clover or other pasture. In Florida and southern Georgia the watermelon crop is harvested in ample time for planting velvetbeans or cowpeas the same season.

Well-rotted manure (free from wilt) is helpful in the furrows under the hills, covered 2–3 inches deep with loose soil. It may also be applied broadcast, and plowed under before seeding. A mixed fertilizer, e.g., 5-10-5, is useful on many soils at the rate of 500–800 pounds per acre. A sidedressing of nitrogen fertilizer often is beneficial.

Seeding and Spacing

About 1 pound of seed is sown per acre; with small seed, e.g., Missouri Queen, ½ pound is enough. The spacing varies. One recommendation is 8–12 feet between rows and 6–8 feet between hills. Another recommendation is in hills 10 × 10 feet apart or every 2–4 feet in drills 10 feet apart. Spacing 7 × 14 feet apart gives about the same number of plants per acre as at

10 × 10 feet, but may provide greater access of plants to fertilizer that is applied continuously in the drill. On the poorer soils, and where the market demand is for a large melon, 12 × 12 spacing of hills may be best.

Sowing begins [26] in southern Florida during late December or early January, in southern Georgia during March or early April, and in the northern commercial sections about May 10–20. Because the young plants are easily injured by frost, the seed should not be sown until the soil has become warm and danger of frost is past. To avoid the chance of crop loss from frost, growers may make an additional sowing 3–5 days after the first, setting the seed 3–4 inches from the rows of the first sowing. Sometimes a third seeding is made to ensure a stand.

Thinning of Plants and Fruits

When grown in hills thinning may be done to 1–2 plants per hill to encourage large melons. The thinning is done after the dangers of frost, cucumber beetles, and cutworms have passed and when the plants are well established. The plants usually will have their fourth or fifth true leaf, and may have begun to run. Row plantings are thinned to a single plant every 6–8 feet.

All but 2–4 well-shaped fruits on each vine are removed when they are 3–4 inches in diameter to encourage those remaining to reach a better size. If "goosenecks" and "nubbins" are removed fairly early, the plant's resources are utilized more fully in developing perfect fruits. Sometimes 3–4 melons are left at the first thinning and the 2 best ones are left at a second thinning, made about a week after the first. On comparatively poor sandy soil it may be wise to leave only 1 fruit per vine until the melon is about 6 inches in diameter; then allow a second melon to form. Thinning should be done only when the vines are dry, so as to avoid spreading anthracnose.

Some growers use a long-handled knife or cutter to snip off the undesired melons. Others use a penknife, because they think the person doing the thinning should examine the melons more carefully than he can without stooping. A cutter can easily be made by sawing a slit in one end of a broomstick, inserting a thin piece of steel, fastening the steel with rivets or screws, and sharpening its outer edge. In thinning with a cutter, the operator places the blade on the stem that attaches the melon

to the vine and with a slight downward thrust severs the stem close to the melon, taking care not to cut or injure the vine.[26]

Some of the smaller varieties are not thinned so closely, 4–6 melons being left on each vine. Even when the normal price differentials favor the larger sizes, it does not seem profitable to thin the Hawkesbury type in Indiana.[163]

Harvesting

The fruit is cut from the vine with about 2 inches of stem. Only melons from strong, healthy vines should be marketed. Melons grown on weak plants or picked from unhealthy, dying vines are rarely of good quality. Only ripe melons should be picked; "green" melons may depress market prices. The best time to pick and to determine and obtain high quality is early in the morning.

A good yield in the South is 400–500 melons per acre, but many growers obtain only half this quantity. Yields of marketable melons usually average about 1 carload to every 2½ acres. In many cases, owing to adverse weather and other difficulties, the yield is as low as 1 carload to 5 acres. The more efficient growers harvest a carload from 2 acres.

There is little real evidence of a change from immaturity to maturity. Size of fruit and color of rind are not good guides. Some of the more useful indicators follow: (*a*) The sound emitted when immature watermelon is rapped with the knuckles is metallic and ringing, whereas when the watermelon is ripe the sound is muffled, dull, or "dead." This test is most reliable in the early morning, for during the heat of the day, or after melons have been picked for some time, they all sound ripe, regardless of stage of maturity. (*b*) The color of the white spot where the fruit rests on the ground takes on a yellowish tinge as maturity is approached. (*c*) The tendril at the place of attachment of the fruit stem and vine usually dries with maturity.

There is a marked decrease in the sugar content from the seed to the rind area. As one example: [238] the center flesh, including the surrounding tissue near the seed area, is 12.6 percent; the flesh near the rind is 9.3 percent. The blossom end is almost 2 percent higher in solids than the stem end; likewise samples near the upper rind are higher in solids than those near the ground.

Before harvesting, large fields can be divided into sections of about 6 rows each. The vines in the center of each section are turned out of the middle to form a roadway. But the vines should be trained this way when forming and should not be disturbed again after fruits have started to develop.

Care should be taken in handling the melons to prevent injury. They should be placed on sides and not on ends. A 5-inch layer of straw in the bottom of the vehicle and padding the sides will help to prevent damage. Melons should not be loaded more than 5 deep.

Breakage of watermelons in shipment is of great concern to growers, shippers, and transportation agencies. Direct measurements of the breakage strength of cut sections of watermelons indicate that: [9] the greater part of resistance to breakage is due to characteristics of the flesh; hollow heart is the factor most conducive to breakage, although other flesh characteristics, not easily defined, are also important; toughness of the rind is second in importance; diameter of the melon and thickness of the rind are relatively minor factors in respect to breakage.

The high-quality Garrison variety is grown on about 16,000 acres in South Carolina.[26] Tenderness of rind makes shipping impractical unless special precautions are taken in packing. One plan is to pack for shipment in layers separated by excelsior.

Storage

When harvested ripe and handled carefully, watermelons keep well for 1–3 weeks at 36–40°F. and 80–85 percent relative humidity. They can be shipped long distances, even without refrigeration. Color, sugar content, and flavor, the chief attributes of a ripe watermelon, do not increase appreciably after it has been picked, but there is a gradual softening of the pulp around the seed.

Insect and Disease Control

Important insect enemies of the watermelon include *cucumber beetles* and *melon aphid*. These pests have been discussed earlier in this chapter.

Anthracnose affected foliage appears scorched and has black spots. Oval to circular sunken lesions, which may be covered with pink spore masses, occur on the fruits. Controls are: treat-

ing the seed (see Table 5), and planting moderately resistant varieties like Congo.

Fusarium wilt affected watermelon seedlings may rot before emerging, damp-off, or be stunted, or the vines may turn yellow and wilt. When the stem is cut across, the inside is dark. Resistant varieties include Hawkesbury, Improved Kleckley Sweet No. 6, Leesburg, Blacklee, Klondike R7, Missouri Queen, and Miles.

Stem-end rot is primarily a transit disease. Control is to leave the stems 2–3 inches long when first cut, after loading clip the stems again, and then disinfect the cut ends with copper sulfate paste.

14 · MISCELLANEOUS VEGETABLES, MUSHROOMS, AND HERBS

GLOBE ARTICHOKE

The edible portion of the globe artichoke is the immature flower head. Its commercial culture in America is mostly limited to a thin strip of coastline that starts near San Francisco and runs about 100 miles south.

As yet the market demand for artichoke is mostly in regions populated by peoples of Latin or South European descent. Canned heart of artichoke (small sizes of buds) appeals more

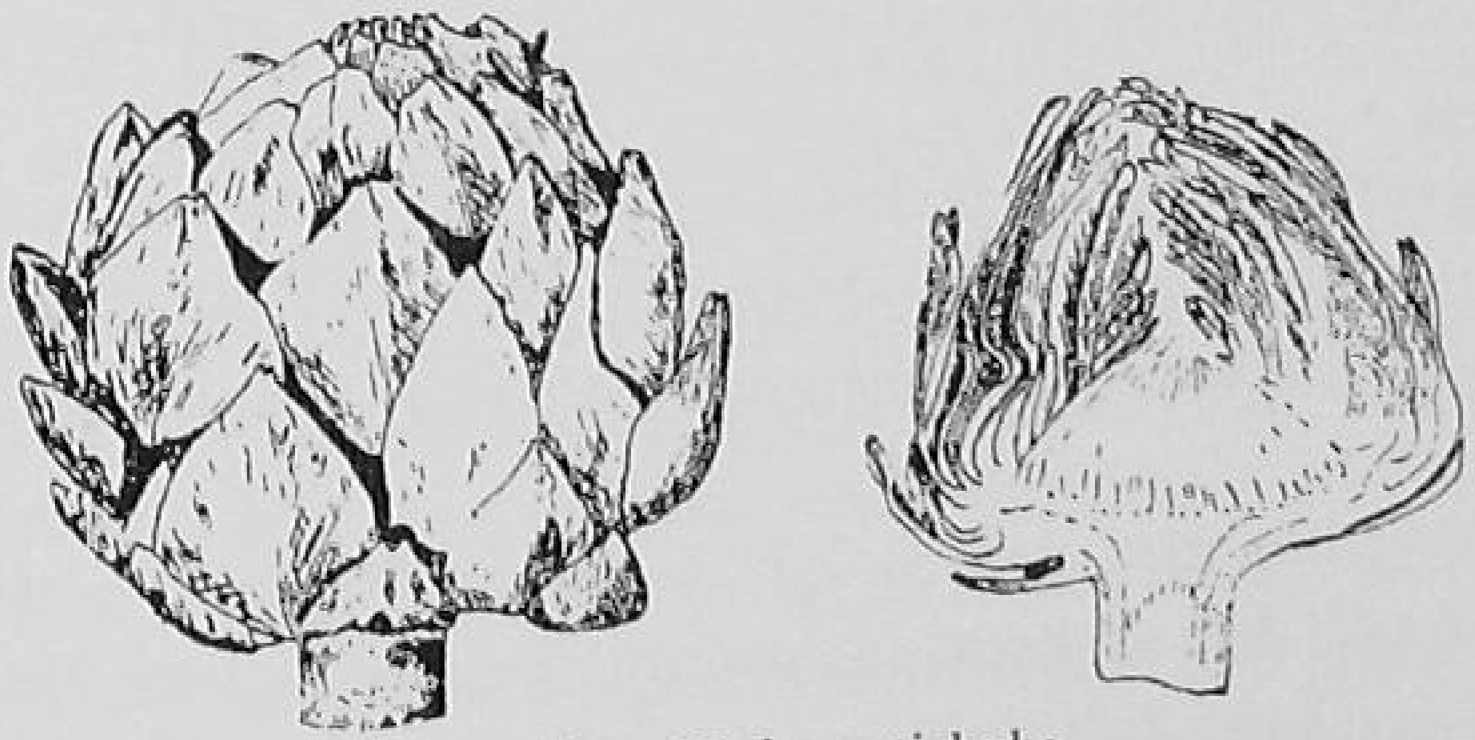

FIG. 72. Globe artichoke.

than the green bud to most consumers. The canning of small buds extends the production period in California well into spring and provides an unusual and easily used salad ingredient.

The tops of the plant die down each year but are renewed again from the crown below the soil. The marketable portion, or "bud," is made up of flower buds and numerous bracts or scales, closely laid one upon the other. The buds are 1–4 inches in diameter.

There are 12–20 dormant buds in the axils of the rosette leaves of the newly set root section at the end of the first growing season.[339] When conditions become favorable, 6–8 of these buds

produce shoots, each of which forms a rosette of leaves and, later, a flower stem. These die after the second season. At the start of the third season, 6–8 buds at the base of each stem again produce shoots. This process is continuous. Each new shoot is thus a lateral branch arising from a bud at the base of the flower stem of the preceding season. Under cultivation, cutting the old flower stems about 4 inches below ground reduces the number of shoots.

Normally new growth begins with the advent of the rainy season, the edible buds forming the next spring. But by irrigation and the cutting back of old stems the plant will grow and produce longer and later. If the buds are not removed, they develop into large heads of thistle-like flowers.

Propagation is usually from offshoots from the rootstock, which form in late summer after harvest. When 10–18 inches high, they are separated from the parent with a spade and planted, in fall or winter. Another method is to take root sections from old plants by pulling or cutting off the base of old stems, thus securing a planting section several inches in diameter and 6 inches or more long.

The plants are set 6–8 inches deep and 6 × 8 feet apart. The top is cut off several inches above the soil. Fall or early-winter planting is advised. Commercial plantings are good for 4–5 years.

In harvesting, the stem is cut 1–1½ inches below the bud, when the bud has attained maximum size but before the bracts begin to separate. In California, a small crop of buds is harvested in the spring after planting. After the picking period is over, the plants are allowed to dry, and the tops are cut off just below ground and burned, or the stems and leaves may be cut, chopped, and ensiled for feeding dairy cattle. After 6–8 weeks of rest, growth is started by irrigation. The new plants develop during summer, and bud production starts in early fall. Development is slow during the cooler months, and the pickings are light for a time but increase rapidly to a peak in March. Yields in California average about 2 tons of buds per acre.

The Creole type is grown in home gardens in Louisiana, but aphids are a serious problem there. In the Creole type the scales (bud) point outward, whereas those of the California type fold

inward in cabbage-like fashion. The "chards" of England are the blanched summer growth of globe artichoke.

COLLARD

Collard is a vegetable grown in the South for greens. Its culture is much the same as for cabbage. It withstands heat better than cabbage. Collard does not form a true head but instead a large rosette of leaves, which may be blanched by tying together or covering. *Vates* is an improved form from the Virginia Truck Experiment Station. "Collard" is a corruption of *colewort* or *colewyrt,* Anglo-Saxon terms literally meaning "cabbage plant."

CRESS

Water Cress

Water cress is desirable for salads and as a garnish. Of prime importance for a commercial bed is a good supply of spring water from which some nutrients, especially nitrogen, are derived and by which higher temperatures are maintained during winter. Where most cress is grown in Virginia [344] the water temperature is 55–58°F.

The flow of water determines to a large extent the size and shape of the bed. The sections should be small enough to afford a uniform distribution of labor and a uniform flow of fresh cress to market. Flood waters can be prevented from injuring the bed by constructing a by-pass which would also make possible the draining of the bed for repairs, grading, and pest control. The cress is cut about every 4 weeks.

On a small scale, a trench may be dug in a shady spot. The bottom is made rich and the seed is sown or cuttings set out in early spring. The soil is kept quite moist. The leaves may be gathered in all seasons except when the plants are flooded to avoid freezing. Water cress can also be grown in pots on saucers of water placed in the shade or under greenhouse benches where it is watered by moisture from above.

Garden, Fine-Curled, and Upland Cress

Several species of the mustard family are involved. The finely curled type, or pepper grass, grows quickly. The seed is sown

early to take advantage of the cool weather; it quickly bolts under dry conditions. The seed is fine and must not be covered deeply. The plants are thinned to 4–6 inches in the rows. Cresses are used while young for flavoring salads, for garnishing, or as a green in sandwiches.

ENDIVE

Endive, or "winter lettuce," resembles lettuce in its culture, but it is blanched. It is usually grown as a fall crop. It is more strongly flavored (nutty) than lettuce. There are two types: (*a*) finely curled or fringe leaved, e.g., *Pancalier, Green Curled,*

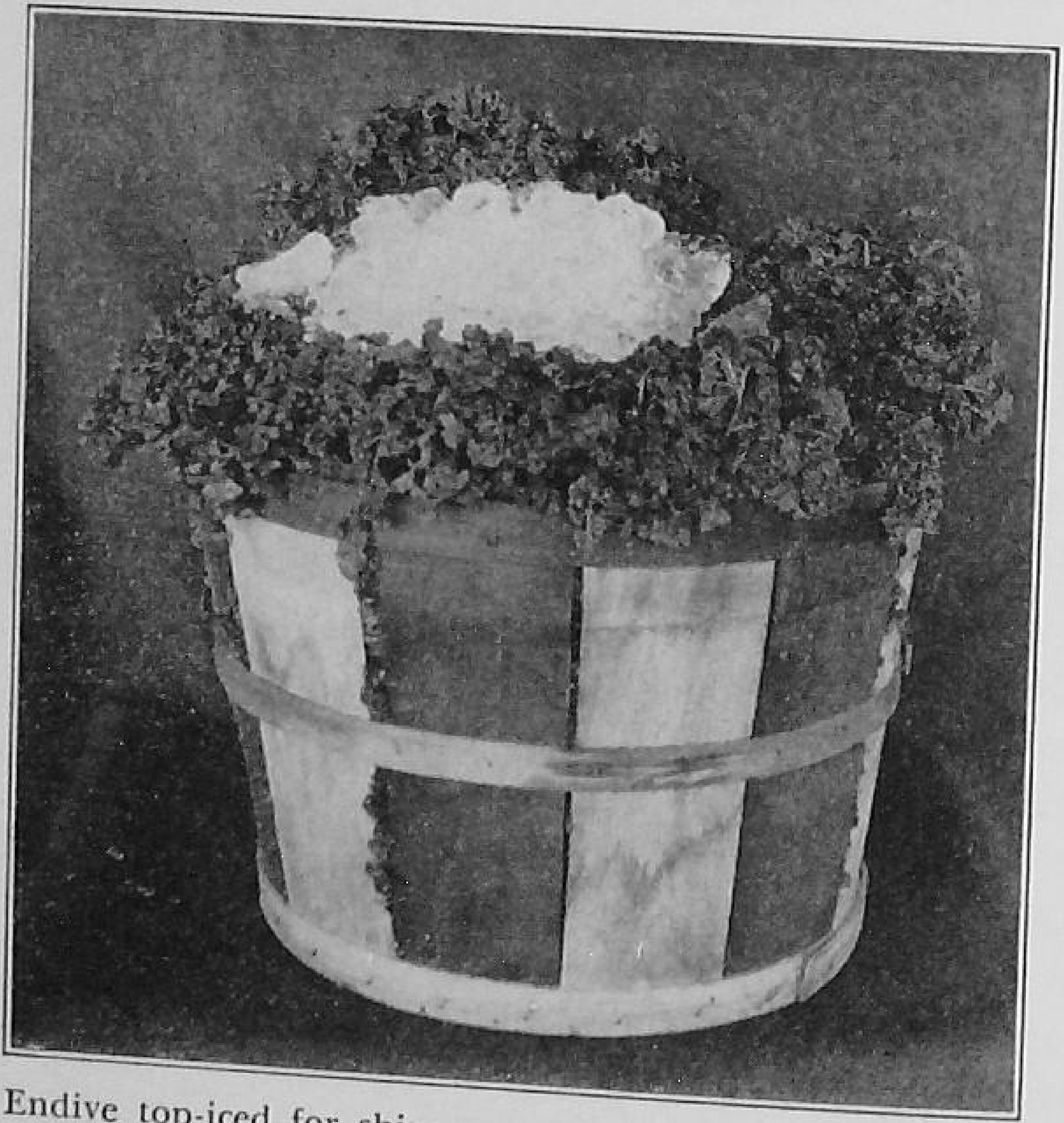

FIG. 73. Endive top-iced for shipment. (*Courtesy Florida Agricultural Extension Service, Gainesville, Fla.*)

White Curled, and *Deep Heart Fringed* (All-America, 1940); and (*b*) broad leaved, e.g., *Batavian, Full Heart* (All-America, 1934), and *Cos-type Batavian* (All-America, 1941). The broad type, shipped green or partly blanched, is called "escarole." The curled type looks the nicest on the table and is the best for salads. The broad type is better for stews. "French endive" is Witloof chicory.

Partial blanching improves the flavor and makes the leaves more crisp, tender, and attractive for salads. One blanching method is to bunch the leaves, when they are dry and the heart is nearly mature, and tie them near the top. Blanching may be done with 2 boards fastened together over the row like an inverted V, or by covering with heavy paper or straw. The plants should be examined frequently in warm, moist, or rainy weather, and the covering must be removed if the hearts begin to decay.

MUSHROOM

Mushrooms are usually grown as a fall, winter, and spring crop in special structures where the required temperatures can be maintained and where other necessary conditions can be provided. They are a difficult crop to produce.

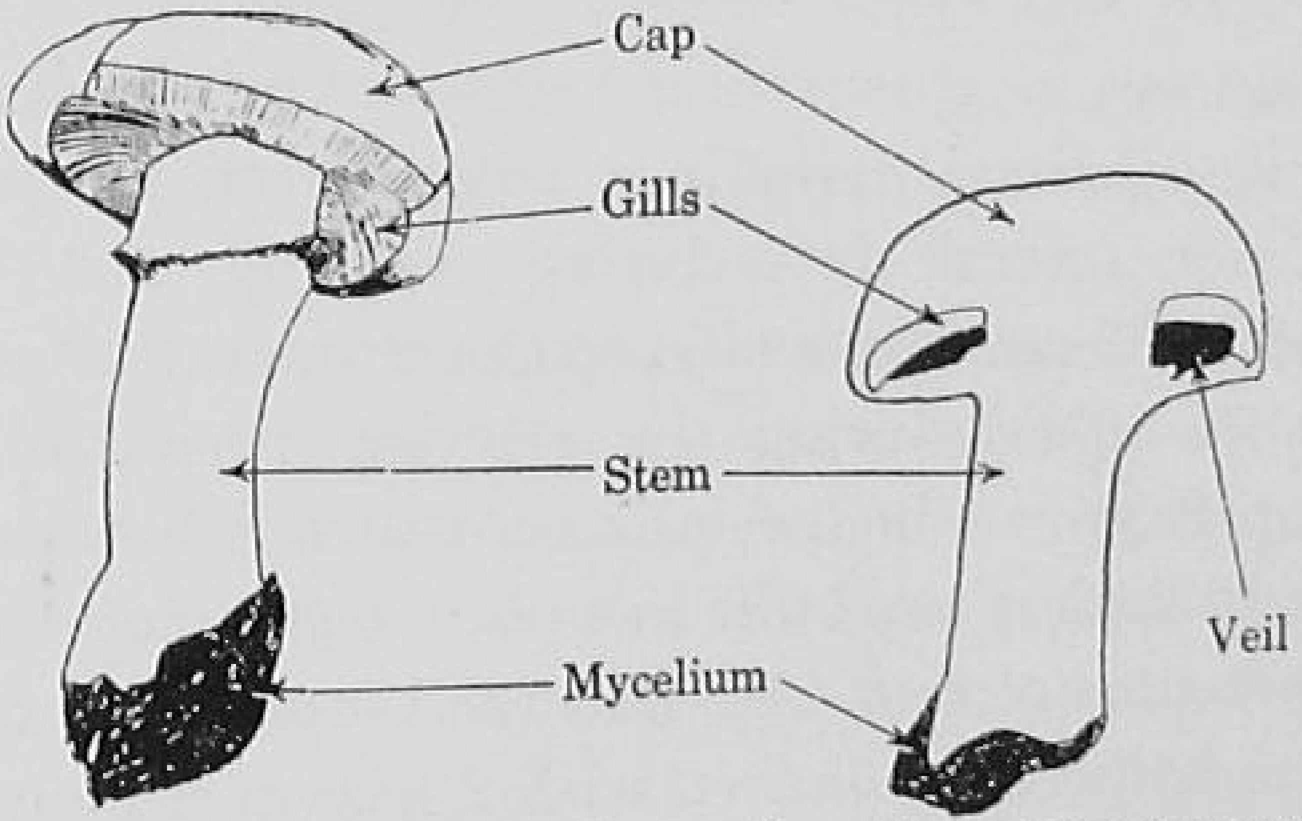

FIG. 74. Diagrammatic illustration of mushroom parts.

The parts of a mushroom are: the cap or pileus, or expanded umbrella-like portion at the top; the stem or stripe, which bears the cap; the gills, or plate-like folds on the underside of the cap on which the spores are borne; the spores, which are microscopic bodies, similar in function to seed; the veil, a membrane-like structure, which, when young, covers the gills and reaches from the margin of the cap to the stem; and the mycelium, which corresponds to the roots of higher plants, being the white, more or less cottony and thread-like strands that run through the beds, from which the mushrooms develop.

A basic difference between mushrooms and green plants is that green plants can manufacture their own carbohydrate food but mushrooms cannot. Therefore the mushroom mycelium must

grow in organic material containing carbohydrates, such as sugar, starch, cellulose, or lignin, as well as the mineral nutrients needed by green plants. Mushrooms also differ from most green plants in having a full root system before they appear aboveground. Poisonous mushrooms do not grow on the medium or under the conditions properly used for growing the common mushroom.

The life cycle begins with the germination of the spore, which gives rise to thread-like mycelium. This mycelium seeks, absorbs, and transports food and usually grows extensively underground during a period of weeks, before concentrating the food in central points and appearing on the surface to produce mushrooms. The mushroom completes the life cycle by producing and liberating spores, which are found on the gills radiating from the stem on the underside of the cap.

Structures for Growing Mushrooms

Mushrooms can be grown in any structure where it is possible to control ventilation, maintain a pasteurizing temperature of 130–145°F. for several days during sweating out, provide a humidity of 70–85 percent, and keep the temperature at 50–65°F. (preferably 54–58°F.) during the growing period. The commercial crop is grown in specially constructed houses. A good bed for mushrooms is one built in tiers, 2 feet being left between the bottom boards of each bed, and the bottom bed 6 inches off the floor. A house 20 × 65 feet, with 2 tiers of 6 beds each, contains 4,320 square feet of bed space. A ton of manure will fill 70–100 square feet of beds 6–8 inches deep.

Preparation of Compost

The best raw material for mushroom compost is manure from grain-fed horses and a moderate amount of wheat-straw bedding. Manure should be fresh from the stable, and it must be composted. The mushroom lives on the products of this decomposition.

A good height of pile is 4–5 feet; this will recede a foot by filling time. The piles are left standing for 3–10 days or until the interior becomes 120–160°F., and then they are turned while water is applied, the lumps are broken up, and the sides of the heap are turned into the center. Weekly turning aerates the pile, breaks up and mixes the manure, causes the fiber to break

down and the ammonia to be dissipated, and encourages proper moisture content throughout the pile. At the last turning 15–20 pounds of gypsum, or 10–15 pounds of superphosphate, per ton of manure are added as a "conditioner" to avoid or overcome adverse conditions in the pile.

Too much water makes the compost "greasy," favors a plaster-mold disease, and retards development of the mushroom mycelium. Soggy manure, especially near the end of the composting period, is a common cause of failure. But too little moisture retards decomposition and causes excessive drying out and burning. When composted the manure should be a fairly uniform dark chocolate brown, moderately speckled with white; the straw is pliable enough to shear off readily when torn crossways; on squeezing, the compost moistens the hand without water running out and at the same time is sufficiently moist and decomposed to remain in a ball when so molded. When this stage is reached the compost is ready for the beds. It is let stand 2–3 days after the last turning in order to obtain uniform moisture and heat throughout the pile.

If manure is not decomposed enough the mycelium grows slowly, molds and other diseases may develop, and maximum yield does not occur. Before the beds are cased, long-stemmed, umbrella-shaped fungous weeds ("ink-caps") which exude a black liquid may appear. They signify undercomposted manure. They should be picked off. If manure is overcomposted the beds will not heat up properly, trouble from insects and diseases may result, its "food" value is lowered, and a maximum crop is not attained.

The object in a mushroom compost is different from that sought in organic fertilizer for green plants. Although manure distributed in the soil adds amounts of nitrogen, phosphorus, and potash, the primary use of a mushroom compost is to supply abundant carbon compounds, since the mushroom cannot manufacture these substances from carbon dioxide and water as do green plants.

Filling the Beds

Houses that have previously produced mushrooms should be disinfected before planting a new crop. Manure compost is moved into the beds at the rate of 1 bushel to 2 square feet of

bed, or so that it is 6–8 inches deep. In small or narrow beds a depth of 8–10 inches may conserve moisture better. After the beds are filled, they are tamped by hand with a tamper (made from a 1-inch board 12 inches square with a handle on the back) to make them firm and level.

Spawn and Spawning

Brick spawn is now obsolete in commercial mushroom growing. Modern spawn is pure-culture spawn. It is prepared by inoculating specially prepared bottles of sterilized horse manure, rye grain, tobacco stems, or other medium with the germinated spores of the mushroom. These cultures are protected during the growing period from outside contamination by a plug of cotton inserted into the mouth of the bottle.

Pure-culture spawn is sold as (*a*) wet, moist, or fresh spawn (just as it comes from the drawing room), and (*b*) dried spawn (removed from the bottle and dried on racks with slightly warmed air blown by fans). Wet spawn should be used within a week or if kept longer should be stored at 35°F. Wet spawn is used by most commercial growers, except those located at a great distance from a spawn laboratory. Dried spawn is usually made from manure spawn or tobacco process spawn. Dried spawn is in a dormant stage. It can be kept in a cool, dry place for a year or more without deterioration. It is several days slower than wet spawn in starting when planted in a bed. Dried spawn is used for export shipment and for seed houses for sale to amateurs.

Spawn (manure, grain, or tobacco) is planted at the rate of 1 bottle to 40 square feet of bed space. Manure spawn is broken into pieces the size of a walnut. The pieces are laid 8–10 inches apart both ways on the bed, at least 4 inches from the side boards. After the bed is covered with spawn measured off in squares, the thumb is inserted, the manure is lifted to the depth of 1½–2 inches, and the pieces of spawn are planted. The manure is then patted back into place. After the beds are planted they are again tamped. Tobacco spawn is gently crumbled before planting. About a teaspoonful of the spawn, spread over an area of about 2 inches, is placed as described for manure spawn. With grain spawn, a small handful is sprinkled into each hole. Broadcasting the spawn is being practiced to an

increasing extent commercially, particularly by growers using the tray method.

The spawn is planted when the temperature in the compost in the beds has dropped to 75–80°F. The mycelium develops fastest if a temperature of 72–75°F. is maintained for 7–10 days after spawning. The temperature is then dropped slowly to 68–70°F. until just before the beds are cased, when it is slowly dropped to 60–62°F.

Casing

Casing means spreading about a 1¼-inch leveled layer of fairly dry soil over the bed, 3–4 weeks after spawning, when the spawn will have run well through the manure. The mycelial growth can be seen by lifting the side boards. Good casing soil holds water well and does not form a crust when it becomes dry. A slightly alkaline loamy soil (*p*H 7.2–7.5) is best. It is sifted first through a ½-inch mesh screen and then tamped lightly after being applied.

Temperature

A slow crop (52–55°F.) will last 5–6 months, whereas a fast crop (56–60°F.) will last only about 3 months. The cooler temperatures result in somewhat larger, firmer, and heavier mushrooms than the higher ones, but the total yield from either is about the same.

Humidity

The relative humidity in the mushroom house during cropping should be 70–80 percent. If it is lower than this, the casing soil dries out too rapidly, and the mushroom caps become tough and sometimes cracked. If it is too high, any water spattered on the caps dries slowly and "spot" results.

Watering

The two chief objectives in watering the beds are to maintain the proper soil-moisture content for an abundant growth of healthy mycelium and to minimize the number of spots and blemishes on the caps caused by spattering. A good plan is to begin watering the beds lightly every day as soon as they have been cased. Several light waterings are preferable to a few heavy

ones because of the danger of excess water leaching through the soil and forming a wet layer of manure just under the soil. Such a layer may prevent the mycelium lower in the bed from growing up to the soil. But if the soil is too dry or if only the surface is moist, fewer mushrooms will develop, and they will tend to form beneath the soil layer rather than on the surface.

The mushrooms develop in "flushes" at intervals of about a week, followed by periods during which there are only a few on the beds. Advantage is taken of the lulls to water, and once the "break" begins watering is stopped until it is over. After 4–5 breaks the mushrooms may become light and spotted, and then it is well to rest the beds for 2–3 weeks.

Sprinkling is best done just after picking, as mushrooms touched by water turn brown and rot; and "buttons" that have been so exposed are picked after watering and destroyed. Tepid (80°F.) is better than cold water for sprinkling the beds. The walks and walls of the houses and the framework of the beds are wet down frequently to raise the humidity.

Harvesting

Mushrooms may appear 35 days after spawning. But 6–8 weeks normally elapse after casing before enough appear for picking to start. Unduly slow growth may be due to poor spawn, improperly composted manure, too many shavings in the manure, low temperature, or unsuitable moisture.

Mushrooms are pulled with a slight twist, rather than cut. This removes the stump, which would otherwise decay and contaminate the bed. If fleshy stumps remain in the bed after large clusters are picked, they are removed and the holes filled with fresh soil. Mushrooms are best gathered about 12 hours before the veil would normally break. At this stage they are 1–3 inches in diameter.

Yield

The commercial grower should obtain 1–1½ pounds per square foot of bed per 3-month crop, 2 crops a year. About 2–3 pounds of mushrooms per square foot is a good yield for a 5-month crop, 1 crop a year.

In Ontario, the schedule is so arranged that the crop is about completed by June 15 as it is not possible to grow mushrooms

during the summer, except in air-conditioned houses. The growers usually plan to take off 2 fast crops per house per year. The houses are usually filled in August and September and cropped until December or January. Then they are cleaned out, disinfected, and refilled immediately, and production is carried on until the high summer temperatures preclude further cropping.

In the 1-crop system, the houses are filled in September or October and are kept in production until May or later. With this system, some growers give the house a rest after it has been in production for 5–6 weeks. During this rest period no watering is done, but any mushrooms that appear are picked. After about a month, the beds are again watered thoroughly and the house is brought back into production.

Containers

The 4-quart Climax basket, holding 3 pounds of mushrooms, is the chief container. Mushrooms also are packed in ½-pint and 1-pint cups or in ½-pound and 1-pound cups or folding boxes, packed 8, 12, 16, or 24 to the carton.

Insect and Disease Control

Mushroom flies can be controlled with DDT, but it should not be used on the beds after spawning or during the cropping period. Partial control of *mites* is obtained by spraying with nicotine. Fumigation and early high temperatures help in the control of various insects.

MUSTARD

White Mustard is a vigorous plant that quickly bolts to seed. The leaves are dark green and useful in salads when young. The large, pale-brown seeds are made into table mustard, especially in the British Isles. *Black Mustard* (Trieste Mustard) is grown for its pungent seeds which are made into table mustard. Mustard is also used for mustard oil, soap, textiles, lubricants for precision machinery, and many other things. About 45 million pounds of mustard seed are produced each year in the United States and Canada. The chief areas are Montana, California, Washington, Oregon, North Dakota, Nebraska, and Alberta. *Brown Mustard* (India Mustard) is inferior in quality to the

black and white mustards as table mustard. A yellow-seeded form of brown mustard, of Chinese origin, is grown in Montana and elsewhere in the Northwest, under the name of Oriental, or McCormick, Mustard.

A. Leaf mustard (*Brassica juncea*).
  1. Curled leaves: Curled Mustard, Southern Giant Curled, Prizewinner.
  2. Broad leaves: Florida Broad Leaf, Elephant's Ear.

B. Mustard spinach (*B. rapa periviridis* or *B. campestris chinensis*): Tendergreen.

C. White celery mustard (*B. chinensis*): Pat Choc.

Southern Giant Curled (All-America, 1935), *Prizewinner* (All-America, 1951), and *Tendergreen* are three of the best varieties for greens.

The seed for greens is sown in rows at least 2 feet apart and the plants are thinned to at least 6 inches apart. The crop, which is cut when quite young for greens, may be sown at periodic intervals.

OKRA

The okra plant is very tender to frost, grows best in hot weather, and needs a long season with warm nights. It is native

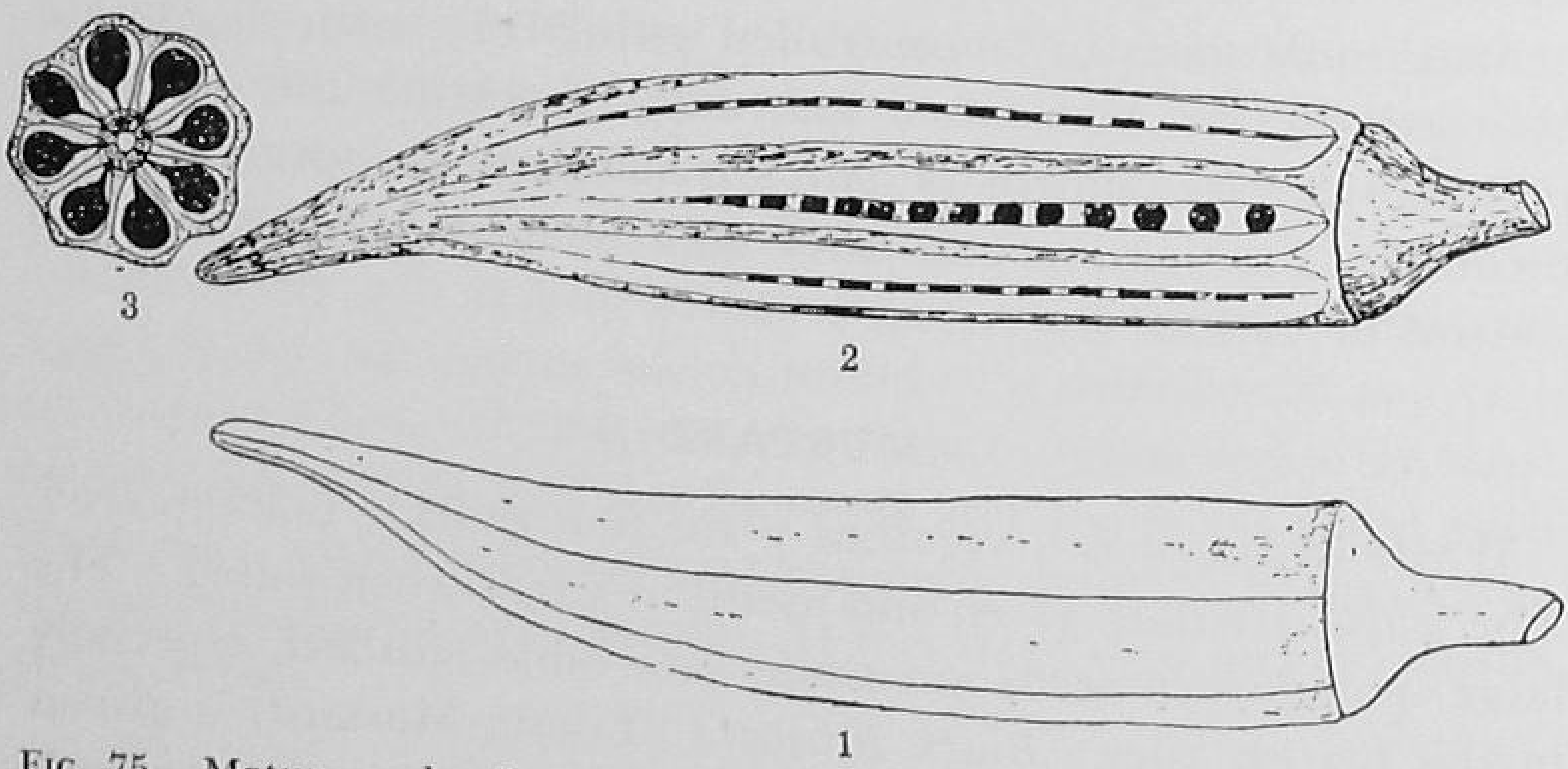

Fig. 75. Mature pods of okra. 1, Green pod; 2, ripe pod, the cells having opened along the sutures; 3, cross section showing the position of the seed. (*After Woodruff*.[439])

to Ethiopia. It was taken to Arabia, down the Nile, by the Moors to Europe, and to Louisiana in the early 1700's by the French colonists.

The pods are the edible portion. In soups okra imparts a flavor and a glutinous consistency or body known as gumbo. Thousands of tons of okra, grown in the South, are sliced and prepared in brine for commercial canners of soups and related products. It is also used in stews and various "creole" dishes.

Okra may be classified into tall, medium-tall, and dwarf and further according to pod length and pods that are either with or without distinct longitudinal ridges. Some leading varieties are Dwarf Green, White Velvet (Ladyfinger), Perkins Mammoth Long Pod, Perkins Spineless, Clemson Spineless (All-America, 1939), White Lightning (All-America, 1939), Louisiana Green Velvet (All-America, 1941), Excel Bermuda (All-America, 1948), and Emerald.

Plant Characteristics

Okra is a half-woody, semi-fibrous, annual plant that grows 3–7 feet tall in the South and is propagated by seed. It has an upright, zigzag stem, and 1 or more lateral shoots or "suckers" near the base.

A flower bud appears in the axil of each leaf above the 6–8 most basal leaves. The crown of the stalk consists of several undeveloped leaves and flowers. During rapid growth there may be as many as 10 undeveloped flowers per crown. As the stem elongates the lowermost flower buds develop into flowers, one at a time. There may be 1, 2, 3, or more days between the development of flowers, but only 1 flower appears on a single stem in 1 day. The flowers are open in the daytime only, and for only 1 day. They are white, up to 3 inches across, resemble upturned bells, offer inviting places for insects, and reach full size and are ready to be pollinated by the time the subtending leaf is one-third grown.

There is 1 pod per blossom. The early growth of okra may be divided into three 30-day periods: (*a*) 30 days for germination to be completed and for the plants to become large enough to be easily cultivated, (*b*) 30 days for the formation of the crown of young leaves and flower buds and for the first flower to appear, and (*c*) 30 days for the first dry pods to appear.

Culture

The seed coat is hard and does not absorb water readily. Soaking it about 24 hours (or until it splits) just before sowing increases the rate and percentage of germination. In the South, the seed is sown 8–12 pounds per acre in rows 3½, 4, and 4½ feet apart for dwarf, medium-tall, and tall varieties, respectively, as early after frost in spring as the land is ready. The seed often fails to germinate uniformly, and the stand may be irregular for 2–3 weeks. The spacing in the row after thinning is about 1 foot for dwarf plants and 1½–2 feet for tall plants. In the lower South, successive plantings may be made at intervals of about 6 weeks for a continuous supply of pods throughout the long season.

Harvesting

Except in unusually hot weather, the pod usually reaches a very good stage for eating in 4–6 days after the flower opens. The pods of most popular varieties are only 3–3½ inches long at this stage, and are tender and free of fiber. Pods smaller than 3 inches long are very good to eat, but harvesting at a very small size results in low yields. There is a continuous harvest from the time the first pods develop until frost, if the pods are kept picked and none allowed to ripen seed. During the harvesting season the plants must be gone over at least every second day, preferably every day, for pods of the best size and quality. In Grady County, Georgia, the chief okra-producing center, as many as 30–40 pickings may be made in a year.

One or 2 days' delay beyond the 4–6 day stage may result in pods that are tough and of poor quality. But with Perkins Improved at Arlington, Va.,[87] the 8- or 9-day stage after the flowers open is the best for harvest. Difference in quality at 6- and 8-day stages is small, but yield increases materially between 6 and 8 days, as this is the period of very rapid growth.

To avoid wilting, the pods are taken to the shade immediately after picking. Any container or method of handling that causes rubbing or pressing of the pods will make the bruised edges of the pods turn black. A stinging or itching sensation results from direct contact with the pods, leaves, or stalks, but it is removed

by washing with water and avoided by wearing gloves and long sleeves.

If the pods are not cut when young and tender, the accumulation on the stalk will cause it to become stunted and stop active growth several weeks earlier. A neglect of 1 week's harvest will cause a check in growth that may not be overcome.

In Grady County, Georgia, the yield for fresh market averages about 100 hampers (30-pound) per acre. Processing crops, picked comparatively late into the season, may yield 200 hampers.

ZUCCA MELON

The zucca melon (*Lagenaria siceraria*) needs a long, warm growing season. The very large, elongated fruits, which may weigh 100 pounds, are useful for preserving and candied peel. It lacks flavor of its own and so is more receptive to artificial colors and flavors. The vines may grow 40–50 feet long and at their peak may grow 2 feet in 24 hours. Hand pollination is essential. The first flowers are male, and after ten of these have appeared the first female flower will be noticed. A simple method of pollination is, in the evening, to take off a male flower and tap the pollen onto the female one. Only 1–2 fruits are left per plant. Germination of the seed may be only 50 percent. A transplanting method, with indoor seeding at 70–80°F., rather than direct seeding in the garden is often best.

HERBS *

Herbs are plants that are used for medicinal, aromatic, flavoring, seasoning, or certain culinary purposes. Good cooks know well how they enhance the piquancy of various dishes. The active principle or flavoring quality is due to the presence in the seeds or leaves of certain characteristic essential oils.

A. Annual: anise, balm, basil, borage, chervil, cumin, dill, fennel flower, florence fennel, pot marigold, sweet marjoram, poppy, summer savoy.

B. Biennial: caraway.

C. Perennial: angelica, bee balm, bergamot, burnet, catnip, clary, coriander, costmary dandelion, fennel, ginseng, horehound, hyssop, lavender, lovage,

* Parsley has been discussed in an earlier chapter.

TABLE 4

HERBS

Common and Botanical Name	*Propagation*	*Spacing, In.*	*Height, In.*	*Remarks and Uses*
Angelica, *Archangelica officinali*	Seed	36 × 36	36–20	Stems candied; seeds used to flavor custards and cakes; leaves and stalks in salads
Anise, *Pimpinella anisum*	Seed	12 × 6	18–24	Leaves used to flavor salads, bread, and cakes, but seeds more often used
Balm, *Melissa officinalis*	Seed	18–12	24	Leaves used to give a clove-like flavor in soups, salads, sauces, stews, meats, and potpourris and to flavor tomato cookery
Basil, *Ocimum basilicum*	Seed	15–18 × 12	12–24	In green salads, with tomato or cheese, in fruit drinks, as garnish for a meat platter, and in soups; seasoning for stews, soups, white sauces, dressings; spicing for sausages and roasts
Borage, *Borage officinalis*	Seed	15 × 12	18–24	Flowers blue, profuse, attractive; candied as a sweetmeat and in cordials; leaves used like spinach
Burnet, *Sanguisorba officinalis*	Seed, Div.	18 × 12	24–36	Salads and cocktails given a cucumber-like flavor by the leaves
Caraway, *Carum carvi*	Seed	12 × 6–8	24	Seeds used to flavor bread, cakes, cookies, biscuits, candies, soups, stews, salads, cheese, sauerkraut, and mashed turnips
Catnip, *Nepeta cataria*	Seed	24 × 18–24	24–36	Dried leaves used for flavoring
Chervil, *Allium cerefolium*	Seed	12–18 × 3–6	12–18	Leaves used in salads (potato salad), as condiment in soups and stews, for garnish and for culinary purposes
Chive, *Allium schoenprasum*	Seed, Div.	12 × 1	12–18	Leaves used to flavor soups, stews, salads, omelettes, and sauces; minced or finely chopped in sandwiches
Cicely, sweet *Myrrhis odorata*	Seed, Div.	15–18 × 12–18	30–36	Garnish or flavoring
Clary, *Salvia sclarea*	Seed	18 × 18	24	Leaves used like sage
Coriander, *Coriandrum sativum*	Seed	12–18 × 6–8	24–36	Seeds used to flavor some breads, sausages, poultry dressings, curry powder, mixed spices, and certain liqueurs
Costmary, *Chrysanthemum balsamita*	Div.		24–48	Used like mint
Cumin, *Cuminum cyninum*	Seed	18–15	6	Seeds used to aromatize cheese and flavor bread and sauerkraut
Dill, *Anethum graveolens*	Seed	18–15	36	With cucumbers for dill pickles; vinegar; young leaves and stems as flavoring in soups and sauces; seeds in pastries

Fennel, *Foeniculum vulgare*	Seed	24–30 × 15–18	36–60	Young leaves as garnishes in salads, soups, and sauces; near bloom the tender stems (in their expanded leaf-stalks) used raw like celery or onions
Fennel, florence, *Foeniculum dulce*	Seed	12 × 5–6	36–48	Enlarged base ("apple") used in fish sauces; flavoring for soups and stews; edible portion blanched with earth halfway when size of duck's egg
Fennel flower, *Nigella sativa*	Seed	18 × 10–12	12–24	Seeds used dry or like dill
Geranium, rose, *Pelargonium graveolens*	Cutt.	In pots	In pots	Leaves used to impart a rose flavor, e.g., flavoring apple jellies and in puddings and custards
Ginseng *Panax quinquefolius*	Roots, Seed	6–8		Prized by Chinese as medicine; shade required; roots seldom dug for market before sixth year
Horehound, *Marrubium vulgare*	Seed	12–18 × 12–15	12–36	Leaves, stems, and roots boiled with sugar to make candy
Hyssop, *Hyssopus officinalis*	Seed, Div., Cutt.	18 × 6–8	18	Tender leaves used in salads; will grow in partial shade
Lovage, *Levisticum officinale*	Seed, Div.	30 × 30	30–48	Used like angelica
Marjoram, sweet, *Marjorana hortensis*	Seed, Cutt., Div.	12 × 10	18–24	Tips, leaves, and flowers used to flavor broths, dressings, meat sauces, croquettes, stews, soups, sausage, etc.
Mint, Spearmint (*M. spicata*) Peppermint (*M. piperita*)	Cutt.	6 × 6	6	Leaves used to flavor soups, stews, sauces, jellies, beverages; garnish; used with lamb meat
Pennyroyal, *Mentha pulegium*	Div.	6 × 6	6	Leaves used for flavoring; strong taste
Rosemary, *Rosmarinus officinalis*	Seed, Cutt., Div.	24 × 18–24	48–72	Leaves, flowers, and tender parts of stems used to garnish and flavor stews, fish, sauces, etc; dried leaves to season meats and soups
Sage, *Salvia officinalis*	Seed, Cutt., Div.	12–18 × 6–8	24–36	Dried as flavoring for pork and stuffings of duck, goose, turkey, veal, and cheese
Savory, summer, *Satureia hortensis*	Seed	12–18 × 6–8	18–24	Leaves, young shoots, and flowering tops used in sausage stuffings, salads, and pork pies and boiled with peas; garnish in meats and poultry dressings, and meat sauces; used in preparing broad beans
Savory, winter, *Satureia montana*	Seed, Cutt., Layers	12–18 × 6–8	12–18	Leaves and young shoots used as a condiment
Tarragon, *Artemisia dracunculus*	Cutt., Div., Layers		18–24	Leaves used for making vinegar and to season confectionery, mayonnaise, fish sauces, pickles, salads, and mustard
Thyme, *Thymus vulgaris*	Seed, Cutt., Layers	12 × 8–10	8–10	Leaves or young shoots used to season soups, meat sauces, meat and poultry stuffings, sausages, cheese, and gravies

perennial marjoram, mint, rosemary, rue, sage, winter savory, sweet cicely, tansy, tarragon, thyme.

The following herbs are usually seeded under glass for later transplanting: balm, basil, lavender, pot marigold, sweet marjoram, tansy, and thyme. Most other kinds grown from seed are sown outdoors, although earliness is obtained by transplanting. In a mild climate certain of the herbs can be grown in coldframes during winter. In the South many herbs are grown in the open throughout the year. A number are quite hardy and will live over winter in the open ground, except in the more northern areas. Some of the biennials are grown as annuals because of their tendency to winterkill.

15 · HERBICIDES, INSECTICIDES, AND FUNGICIDES

HERBICIDES

Chemicals used for weed control can be divided into two classes, namely, selective materials and contact sprays or dusts. The former kill certain species of plants but do not appreciably injure others, whereas the latter kill or severely injure all plants that they contact. Another classification is pre-emergence and post-emergence.

Acids

Sulfuric acid can be used in onion fields to control many weeds that are easily wet. The spray nearly always causes some injury to the onions, and so may reduce the yield in some cases. Great care is needed to avoid injury to persons handling the acid. A brass, bronze, stainless steel, or glass-lined pump with a wooden, brass, or lead-lined tank must be used. The spray, 2–2½ percent sulfuric acid by volume, is applied, preferably on a dry, warm (not hot) day at a rate of 100–150 gallons per acre if the entire area is covered, or less if the rows only are sprayed. The spray is most effective on small weeds but is not applied until onions show at least 1 true leaf 3–4 inches long.

Chlorates

Sodium chlorate and a preparation known as Atlacide were used as weed killers along roads, fences, and ditch banks long before the discovery of the organic compounds. They are useful on small areas of perennial weeds where soil sterility for 2–3 years is not objectionable. Erosion factors should be considered.

Cyanamide Ingredients

Cyanamid, in granular form, applied in an 18-inch band on top of the row, when weeds are not more than ½ inch high and

wet with dew, and during or after the cutting season, is a control for many broad-leaved weeds in asparagus. A good rate is 1 pound to 30–40 feet of row. The pulverized or special dust form is used at the rate of 75–100 pounds per acre. Besides killing weeds, Cyanamid supplies nitrogen fertilizer. Cyanamid is also a useful pre-emergence weed control in seedbeds.

Good control of weeds in peas is obtained by applying 250–300 pounds per acre of dustless, granular pellets of the cyanamide with a grain drill or lime spreader before the peas emerge. The chemical, applied a week after seeding, decomposes slowly enough to kill or retard weeds until the peas dominate them.

Cyanamid special grade dust applied to the soil before the onion seedlings emerge, at the rate of 75–100 pounds per acre, does a very efficient job at a fairly low cost. If the granular Cyanamid is used, the seedbed should be finally prepared, as lumps in the soil will cause the granules to roll to one side. The rate is 150 pounds per acre.

Potassium cyanate (KOCN) will kill such weeds as purslane, redroot pigweed, chickweed, lamb's-quarters, and annual grasses, in onions, if applied when the weeds are small and dry. The pre-emergence contact spray is applied at the rate of 8 or up to 12–16 pounds of potassium cyanate in 50 gallons of water per acre. For the post-emergence application, 8 pounds of the material dissolved in 50 gallons of water is applied per acre. The spray is aimed at the base of the onions, and if only the rows are sprayed in a 4-inch band, the amount of material needed per acre is reduced.

The spray application should be followed by at least 4 hours of dry weather. Warm weather hastens the weed kill. It is important to mix a fresh solution for each application, as the material in solution breaks down quickly and becomes ineffective. Onions damaged by frost, hail, wind, drought, insects, or diseases show severe tipburn and should not be sprayed with potassium cyanate until normal growth resumes. If a treatment should fail for any reason to give good control of the weeds, 3–4 days should elapse before repeating the application.

Dinitros

Spraying with a *dinitro,* e.g., Sinox (sodium dinitro-*ortho*-cresylate), is useful for killing weeds in pea fields. The am-

monium salt of dinitro-*ortho*-cresol is as toxic as the activated sodium salt and reduces the weight of material needed per acre from 10 pounds (1 gallon of Sinox) to 3 pounds. The salt formulations are applied, 80–100 gallons per acre, when the weeds are small and the peas are 4–10 inches tall but before bloom.

In asparagus seedling beds, dinitro can be used effectively in the form of an oil-water emulsion or as a water solution. Application is made at the rate of 1 pound in 75 gallons of water or plus water per acre. (See also under Pentachlorophenol.)

Dinitro oil emulsions are useful for quick, temporary removal of weeds and grasses along highways, railroads, and fence rows.

Flame

Burning weeds by means of a flame may help in sweet corn and onion sets. Since dry muck or peat will burn, flame is a fire hazard on such land.

Growth Regulators

There are a number of formulations of *2,4-D* (dichlorophenoxyacetic acid) such as esters, amine salts, and sodium salts. The ester form is somewhat volatile and may, like the dusts, be carried by air currents to sensitive crops. In using 2,4-D all calculations are based on pounds or fractions of a pound of 2,4-D acid; e.g., if a gallon of concentrate contains 4 pounds of 2,4-D acid equivalent and ½ pound per acre of 2,4-D is desired, one would use ⅛ of a gallon or 1 pint. It kills most broad-leaved weeds.

> 2,4-D is a plant stimulant. It speeds up respiration, digestion of plant foods, and use of reserve food. Death is due at least in part to the loss of reserve foods and to the activity of organisms that prey upon the weakened plant. Most plants absorb 2,4-D rapidly. It will penetrate any part of a succulent plant—roots, stem, leaves, flowers, or buds. Once inside, the chemical moves rapidly.
>
> Small amounts of 2,4-D stimulate the growth of new cells in some parts of the plant, deforming it. The veins of young leaves may become enlarged and flattened, and the leaves develop as long narrow strips with curled edges. Even a little 2,4-D may cause stems of succulent plants to grow more rapidly on one side than on the other, giving the plant a bent or wilted appearance and weakening it.[127]

In an asparagus field, 2,4-D deforms the spears it hits but does not affect the rest. It can be used before or after harvest. If

applied during the cutting season, guards should be used or about a week's crop may be lost.

In sweet corn,[314] the safest time to spray is just as the crop is breaking through the soil. Earlier applications can injure germination if rains occur. Later applications are safe until the corn is about 3–4 inches tall. Larger corn can be sprayed but the risk of damage is much greater. Only ½–¾ pound of 2,4-D per acre is needed for good weed control. With a sprayer designed to deliver 10–15 gallons per acre, ½ pound of 2,4-D would be added for each 10 gallons of water in the tank.

In most vegetable crops, soil applications of 2,4-D before seeding, and between seeding and emergence, have generally proved unsatisfactory. The residual effect of pre-emergence sprays may last longer than anticipated and injure the crop. Tomato, bean, squash, and some other sensitive garden plants may be injured if 2,4-D is applied directly to the soil around them; if sown in soil containing injurious quantities they may never come up.

Oils or Petroleum Products

Stoddard Solvent or "carrot oil" is a petroleum distillate that is widely used as a commercial solvent, dry cleaning fluid, and paint thinner. When sprayed on carrot, parsnip, dill, and other umbellifers, it kills many weeds without injury to the crop. The fact that carrot and related plants are not killed by Stoddard Solvent, whereas most weeds and other crops perish, is explained on the basis of a difference in cytoplasmic membranes of the plant cells which prevents the entrance of oil into the cells of the tolerant plants.

Spraying is done with low pressure after the first true leaves are formed and before carrots are larger than a lead pencil. The fluid should have these specifications: boiling range, 300–400°F.; flash point above 104°F.; aromatic spirit by volume 12–15 percent. The fluid works best when applied on a cool, still, cloudy, humid day, and when the plants are not wet from rain or dew. On a very hot, dry, clear, windy day it evaporates rapidly.

Celery in outdoor seedbeds can be sprayed when the seedlings are in the 1- to 2-leaf stage. But celery plants should not be sprayed with this fluid after they have been set in the field.

Applications of Stoddard Solvent to tomato plant beds when weeds are small and before tomato seedlings emerge give good

control without injury to the plants.[291] Weed control also is good when the oil is applied 20–24 hours prior to the emergence of the tomatoes. Best results are obtained when the tomato seed is sown deep so that a maximum number of weed seeds germinate before the tomato seedlings emerge.

The petroleum naphthas are effective as pre-emergence herbicide sprays in both beets and spinach. The weeds must appear before the crop since only the weeds emerged or just emerging are killed. The seedbed is prepared some time before sowing so that many weeds will germinate and the crop can be sown with minimum disturbance of the soil. The spray can be applied after sowing but before the crop seedlings emerge. More effective control is obtained if the spray is applied shortly before emergence of the crop, but it is not always practical to do so.

Stoddard Solvent may be applied to the whole field, or as a 3–4 inch band down the row, *before* onion seedlings emerge. From 20 to 30 gallons are necessary per acre when a 3–4 inch band is sprayed.

Directional spraying of beans with a petroleum weed killer, with a special machine that sprays no higher than the first inch of stem, is comparatively cheap.

Pentachlorophenol

In asparagus seedling beds an effective weed killer is pentachlorophenol applied at the rate of about 7½ gallons per acre. This material is diluted with water (up to 75 gallons for 7½ gallons of weed killer) and emulsified by agitation. As the seed germinates, asparagus sends a root down about 2 inches. Then the seedling rapidly sends a stem toward the soil surface. When the tips of the small stems are ¼ inch below the soil surface, the herbicide is applied. Progress of the germinating seedlings must be watched closely, for if asparagus is aboveground when the herbicide is applied it will be killed or severely injured.

Salt

A concentrated salt solution with a wetting agent will kill many weeds yet cause little or no injury to beets. The spray is prepared by dissolving 200 pounds of common salt (fine grade), or 160 pounds of salt plus 120 pounds of sodium nitrate, in 100

gallons of water. A good agitator in the sprayer is needed. The beets must show at least 3–5 leaves that are 2–3 inches high before they are sprayed. Except for this qualification, spraying is best done when the weeds are small, if possible. About 200 gallons are applied per acre if the entire area is covered, or 75 gallons if the rows only are sprayed. A pressure of 50 pounds is adequate.

INSECTICIDES, FUNGICIDES, AND SEED TREATMENTS

Arasan (see under Sulfur)

Arsenicals

Arsenicals have largely been supplanted by DDT and other more effective materials for chewing insects. Laws regulate the amount of arsenic, lead, and other poisonous residue tolerated on produce offered for sale; hence the materials must be used with caution, in late applications particularly. *Lead arsenate* is held in suspension in water. It adheres well as a spray (1–2 pounds to 50 U. S. gallons *), but this is adverse from the residue standpoint. It contains two poisons, lead and arsenic. *Calcium arsenate* is higher in arsenic oxide but has poorer adhesive qualities. *Paris green* is still higher in arsenic content; more hydrated lime is needed with it than with other arsenicals to avoid plant injury.

Bait

Poison bran mash, e.g., 25 pounds of bran (or equal parts of bran and sawdust), 1 pound of Paris green, 2 quarts of stock molasses, is effective against cutworms. The poison and bran are mixed together dry. The molasses, diluted with a little water, is stirred into the dry materials and made into a stiff but not sloppy mash. The mixture, spread near the plants on a warm evening, is enough for an acre.

A cheap bait, such as freshly pulled, moistened weeds poisoned with Paris green, scattered in a deep furrow made around the planting plus spraying or dusting with a stomach poison helps control the *beet webworm*. This insect occurs intermittently in enormous numbers in the West.

* Fifty U. S. gallons corresponds to 40 Canadian gallons.

Benzene Hexachloride (BHC)

BHC applied to the soil will kill wireworms and maggots. The crude form often taints the flavor of the crops but high gamma-isomer forms are less objectionable.

Bordeaux Mixture (see Copper)

Bromides

Ethylene dibromide (EDB) is a colorless liquid, usually of 10 or 20 percent strength, in thinners such as naphtha. For wireworm control an applicator is used to inject the liquid into the soil 6–8 inches deep at 12-inch spacings.[224] The dosage with the 10 percent material is 2 milliliters (1 fluid ounce is 29.6 milliliters). EDB is applied at least 7–15 days before planting, at 45–70°F., and on soil in a condition ready for planting. Beans, corn, and lettuce seem tolerant of the chemical, but tomatoes and related crops may be injured if planted too soon after an application. One treatment usually continues to give some control the second year.

Methyl bromide (plus 2 percent chloropicrin as a warning agent in case of spilling or leakage) is a soil fumigant for protecting plant beds against weeds, nematodes, soil-borne insects and diseases, according to manufacturer's direction.

Carbamates

Certain "common" names are used to refer to the carbamate organic fungicides, e.g., ferbam (ferric dimethyl dithiocarbamate), and ziram (zinc dimethyl dithiocarbamate), nabam (disodium ethylene *bis*-dithiocarbamate), and zineb (zinc ethylene *bis*-dithiocarbamate). These chemicals are marketed under various trade names: e.g., Fermate, Karbam-Black, and Ferradow for products containing ferbam; Zerlate and Karbam-White for those containing ziram; Dithane D-14 and Liquid Parzate for those containing nabam; and Dithane Z-78 and Parzate for those containing zineb.

Some of these substances seem more effective than copper compounds for certain diseases of tomatoes, vine crops, and beans, and may promote higher yields even though the degree of disease control may be the same. (See Bordeaux Mixture under Copper.)

Carbon Disulfide

Carbon disulfide (10 pounds or 1 gallon for 1,000 cubic feet) is an effective fumigant for weevil-infested pea and bean seeds where insurance or other regulations permit its use; the gas is explosive and inflammable. The liquid is poured into shallow

Fig. 76. Lightning damage (*center*) sometimes occurs in onions on marsh land.

dishes which are placed on top of the seed, or it can be sprinkled directly upon the seed without injury to germination or food value. Fumigation is continued for 24–48 hours at or above 75°F.

Chlorine

Chlordane (like DDT and BHC, a chlorinated hydrocarbon) is useful to control ants, grasshoppers, maggots, and several soil-inhabiting pests such as Japanese beetle grubs and wireworms, but it may present a serious residue problem.

Toxaphene (camphene with 67–69 percent chlorine), 20 percent dust, is useful to control grasshoppers and cutworms, but has some of the disadvantages of DDT.

Chloropicrin

Chloropicrin or "Larvacide" is a tear gas and functions as a soil fungicide as well as killing nematodes, soil insects, and weed seeds. It is very toxic to foliage. Special machines are used to dispense it.

Chromates

A dosage of only 2 pounds per 100 gallons of a copper zinc chromate having suitable proportions of the metals (about 3, copper; 2, zinc; 1.2, chromium) helps control potato diseases, including early blight.[381] DDT is compatible with the copper zinc chromate, e.g., "Crag."

Copper

Bordeaux mixture (e.g., copper sulfate 4 pounds, hydrated lime 6 pounds, water 50 gallons) is a preventative of fungus diseases. A stock solution of copper sulfate is made by dissolving 1 pound in 1 gallon of water. The spray tank is filled two-thirds full of water, the hydrated lime is added while stirring, and the copper sulfate stock solution is poured in. For potatoes and some other crops half the suggested amount of lime gives good control and less trouble from clogged nozzles. Bordeaux should be used the day it is made as the mixture is not stable.

A lack of correlation often exists between control efficiency and yield because phytotoxicity can offset, or even overbalance, the beneficial effects of disease and insect control. When this happens, a pesticide that offers the best balance between control and lack of injury takes first place on the basis of yield. This is frequently illustrated[431] in comparative tests of the fixed coppers and Bordeaux mixture where plots treated with the latter often are lower in yield, although foliage scores show more disease to be present in the former.

The fixed or *insoluble* copper fungicides are of four general types:[257] (*a*) basic sulfates, including the tribasic copper sulfates, e.g., the "Tennessee Tribasic" series, and other basic sulfates such as Basicrop and Bordow; (*b*) the basic chlorides such as copper oxychloride, e.g., COCS; (*c*) oxides, as the red and yellow cuprous oxides, e.g., Cuprocide; and (*d*) miscellaneous copper

silicates, phosphates, zeolites, etc., such as Coposil. The copper oxychlorides are the most effective in disease control but are somewhat toxic to foliage. The sulfates and chlorides are the most widely used. The fixed copper sprays and dusts are convenient to handle, and are often combined with insecticides.

Copper-lime dust (monohydrous copper sulfate, 15 pounds, and hydrated lime, 85 pounds) in the presence of dew on the leaves functions like Bordeaux mixture.

Cuprous oxide powder (red to yellow) is an old control for seed decay and damping-off.* For small seeds, like spinach, celery, and carrot, the dosage for 100 pounds of seed is 1 pound; for large seeds, like squash, it is 4 ounces. Seed and dust are mixed in a tight container until the seed is coated; excess dust is then screened off. When sowing smooth seed with a drill, graphite powder is added; otherwise the friction from the dust retards the flow of seed, interferes with operation of the drill, and may break the seed and so reduce germination. Seed of the cabbage and onion families, corn, lettuce, and limas is harmed by copper.

Beet and spinach seed may be treated with 2 ounces of *copper sulfate* in 1 gallon of water. The seed is tied loosely in cheesecloth and soaked for 1 hour. Pepper seed may be presoaked in water 6–15 hours, and soaked in bluestone (1½ ounces to 1 gallon) for 5 minutes; then it is dusted with air-slaked lime and sown at once.

Use of a copper fungicide may supply enough copper to meet the need for it as a limiting minor element on some soils.

DD (dichloropropane-dichloroproplene)

DD, a dark brown liquid, is a soil pest fumigant. It is applied 2–3 weeks before planting (200 pounds per acre for nematodes †

* *Damping-off* is primarily a seedbed trouble caused by various soil-inhabiting fungi. The seedlings are attacked near the soil surface and wilt, fall over, rot, and die. Since some of the parasites are carried with the seed and others in the soil and all are favored by continuous moisture, the chief controls are seed treatment (see also Table 5), soil sterilization, and keeping the top soil and foliage reasonably dry.

† *Nematodes* (eelworm, root-knot), which are small worms scarcely visible to the eye, cause small galls and other abnormal growth, and weaken or kill the plant. Root-knot is a widespread and serious trouble in sandy soils in the South. One can starve out the worms by growing a resistant crop, e.g., sorghum, milo, kafir, wheat, barley, oats, velvet bean, or sweet clover,

and 400 pounds for wireworms). On small plots, spot injections are made 6 inches deep at intervals; on a large scale, special equipment is used. DD disperses through the soil as a gas.

DDD OR RHOTHANE (dichloro-diphenyl-dichloroethane)

DDD has 1 atom less of chlorine and is less toxic to humans and bees than DDT. It is effective in the control of tomato hornworm, corn earworm, leafhoppers, and many beetles.

DDT (dichloro-diphenyl-trichloroethane)

DDT acts both as a contact and a stomach poison, is very effec-
tive against certain insects, e.g., leafhoppers, corn borers, and
earworms, flea beetles, Japanese beetles, cutworms, and white
grubs. It shows a persistent toxic action, and is compatible with
the common fungicides. It should not be used with a dust that
contains lime. Impure forms will injure bean, cucurbit, and
tomato plants. DDT may remain as an undesirable residue and
may accumulate in toxic quantities in the soil. It is ineffective
against Mexican bean beetles, cabbage and turnip aphids, horn-
worms, and mites, and will kill certain insects that are natural
enemies of others.

DILUENT

A diluent is a relatively inert material that is used as a carrier
or conditioner in dust mixtures. Examples are hydrated lime,
bentonite, talc, kaolin, pyrophyllite, and walnut-shell flour.

ETHYLENE OXIDE, CARBON DIOXIDE MIXTURE

This is composed of 1 part ethylene oxide and 9 parts carbon
dioxide by weight. It is a noninflammable, nonexplosive gas, is
not highly toxic to man, and does not leave any appreciable odor
in the fumigated product. It is useful where insurance or other
restrictions preclude other fumigants. The gas is sold in cyl-
inders under pressure. The usual rate is 20 pounds per 1,000
cubic feet for 24–48 hours in a room at above 60°F. This gas

or by keeping the land clear of vegetation for one or more years. The drier
the soil and the more often it is worked in summer, the quicker the worms
are exterminated. A southern soil infested with root-knot may produce
winter crops, as the eelworms are inactive in cold weather.

is not used with seeds intended for sowing, as germination is injured.

Fluorine Compounds

Sodium fluosilicate, barium fluosilicate, sodium aluminum fluoride, and cryolite contain fluorine as the killing agent and will control certain beetles.

Formaldehyde

In beds and flats, 2–3 tablespoonfuls of commercial liquid formaldehyde per bushel of soil helps control damping-off. The liquid is diluted with 5–6 times its volume of water, sprinkled over the soil, and mixed into it. The treated soil is allowed to stand 24 hours, the seeds are then sown, and the soil is watered well to avoid seed injury.

The cold treatment for potato scab consists of soaking the tubers in 1 pint of formaldehyde diluted in 30 gallons of water for 1½ hours at room temperature, or keeping them moist for 1–2 hours and then soaking them in the diluted formaldehyde for ½ hour.

The hot treatment for scab consists of dipping whole tubers 3–4 minutes in a solution of 1 pint of formaldehyde and 15 gallons of water heated to a constant 125°F. The tubers are kept wet for 24 hours before treatment. A false bottom in the tank helps to keep the bottom tubers from being overheated. As the treated sacks of potatoes are removed from the drain board, they are stacked and covered with canvas or burlap to permit further penetration of the formaldehyde fumes, but only for 1 hour. Then they are dried and cooled rapidly.

For onion smut use 1 gallon of formaldehyde in 64 gallons of water, and drip 1 gallon to 350 feet of row while seeding.

Hellebore

Hellebore, the powdered roots of *Veratrum album* and *V. viridis,* contains alkaloids that are poisonous to insects but not to humans when used in proper dilution. It loses its strength readily when exposed to air but is effective against chewing insects on crops nearly ready to harvest. For sprays, use 1 ounce in 3 gallons of water.

Hot Water

Hot-water treatments may impair germination, especially of old and weak seeds, and so it is well to test small samples before treating large amounts. To ensure a uniform desired temperature is is wise to treat at one time only small sacks half full of seed in relatively large quantities of water and to stir the water during the treatment. Rapid drying is essential, and so the seed is spread in a thin layer and stirred.

TABLE 5

Vegetable Seed Treatments [396]

Vegetable	*Disinfectant*	*Disinfestation*	*Protectant*
Beet	Hot water, 140°F., 10 min.	N.I. Ceresan dust, 0.5%	Arasan, 0.5%
Cabbage, cauliflower, and other crucifers	Hot water, 122°F., 30 min.	None	Arasan, 0.5%
Carrot	Hot water, 125°F., 10 min.	None	Arasan, 0.75%
Celery	Hot water, 118°F., 30 min.	None	None
Cucumber, and other cucurbits	None	Mercuric chloride, 1-1,000, 5 min., rinse	Spergon, 0.3%; or Arasan, 0.3%
Lettuce	None	None	Spergon, 2.0%
Lima bean	None	None	Spergon, 0.1%
Onion	None	None	For damping off: Arasan, 0.5%. For smut: 1-64 formaldehyde; or Arasan, 25% pelleted on seed with Methocel sticker.
Pea	None	None	Spergon, 0.2%; or Arasan, 0.2%
Spinach	None	None	Arasan, 1%
Sweet corn	None	None	Arasan, 0.3%
Tomato, pepper, eggplant	Hot water, 122°F., 30 min.	Arasan, 0.3%; N.I. Ceresan dust, 0.5%	N.I. Ceresan dust, 0.5%

Hydrocyanic Acid Gas

Fumigation with HCN is effective for weevil-infested peas or beans. The gas is very poisonous if breathed even in small quantities, is noninflammable and nonexplosive when mixed with air in fumigation proportions, and does not injure germination or food value. For large warehouses well filled with peas or beans the dosage is 20 ounces of liquid HCN, or 2½ pounds of granular NaCN, to 1,000 cubic feet.

Mercury Compounds

Various mercury compounds are used to control root maggots and to disinfect and protect seeds, roots, and tubers.

Calomel (mercurous chloride). With seed of the cabbage family sown late in the seedbed, and with onions on upland soil, calomel helps control maggot and damping-off. Four ounces of powdered gum arabic are dissolved in 1 pint of hot water; 1½ ounces of this solution are mixed with a pound of seed as a sticker for the calomel. Then 1½–2 pounds of calomel per pound of moistened seed are added and thoroughly mixed. The seed is treated just before it is sown.

Corrosive sublimate. Corrosive sublimate is also called mercuric chloride or bichloride of mercury. It corrodes metals, and so containers made of wood, earthenware, glass, or enamelware are used. One ounce to 7½ U. S. gallons of water is 1-1,000 strength. Seed is treated in bulk or in cloth sacks suspended in the solution. The solution loses strength with successive use.

To test for amount of fresh solution to add, dissolve ⅙ ounce of potassium iodide crystals in 1 quart of water, add 1 gram of copper sulfate (dissolved in a little water), and pour 10 cubic centimeters of this solution into a glass measuring cylinder. Now add fresh corrosive sublimate (1-1,000) very slowly, shaking the cylinder, until an orange precipitate begins to form, and record the amount used. To test the strength of a corrosive sublimate solution that has been used add water to bring it up to its original volume, and then add some of it very slowly to the potassium iodide test solution. When the orange precipitate appears, record the amount of corrosive sublimate solution added. The fraction represented by the original amount over the larger amount shows how much the solution has been weakened; e.g., if 2 parts of corrosive sublimate produced the orange color in the first test and 3 parts were needed in the second test, the solution has been weakened to two-thirds its original strength, and one-third more corrosive sublimate is required.

Whole potatoes of varieties like Green Mountain and Irish Cobbler are treated for ½-2 hours, being kept wet 20–24 hours before treatment. Tubers of shallow-eyed varieties, such as Katahdin, Chippewa, and Sebago, may be injured by this treatment and should be treated only with one of the quick dips followed by quick drying.

An *acid-mercury dip* for potatoes is made from 6 ounces of corrosive sublimate in 1 quart of commercial hydrochloric (muri-

atic) acid and adding this, or Mercurnol, to 25 gallons of water at 50–70°F. The uncut tubers are soaked in it for 5 minutes. This quantity will treat 10 bushels of potatoes. They are drained and dried quickly to avoid injury to their eyes and skin.

As a seed treatment, corrosive sublimate is used chiefly for cucurbits (see Table 5).

YELLOW OXIDE OF MERCURY. Two pounds of yellow oxide of mercury (technical grade) added to 30 gallons of water in a wooden container, or in a metal container painted inside with asphalt, serves as a quick dip for rhizoctonia canker of potato.[110] The mixture is stirred with a wooden paddle until all the oxide is in suspension. A basket (e.g., a wire basket painted inside with asphalt paint) of seed potatoes is then dipped into the liquid and plunged up and down several times to ensure complete wetting of the tubers and to keep the solution well stirred. The tubers are then dried. Thirty gallons will treat 200 bushels of potatoes. Any mercury treatment may increase common scab where the soil is alkaline enough for this disease.

ORGANIC MERCURIALS. A number of organic mercurials are useful for seed and bulb treatment, soil disinfection, and damping-off control, at manufacturer's directions. Some examples are: Ceresan (2 percent ethyl mercury chloride), New Improved Ceresan (5 percent ethyl mercury phosphate), Semesan (30 percent hydroxymercurichlorophenol), Semesan Jr. (1 percent ethyl mercury phosphate), and Semesan Bel (12 percent hydroxymercurinitrophenol), Barbak C (8 percent phenyl mercury cyanamide plus 1 percent cadmium oxide), Corona Merko (ammoniated hydroxymercury compound containing 3.5 percent metallic mercury), Sanoseed Potato Dip (7.0 percent ethanol mercuric chloride), Corona P.D. 7 (5 percent mercury, 2 percent bromine, and 7 percent phenol), Ceresan M (7.7 percent ethyl mercury *para*-toluene sulfonanilide), Leytosan (7.2 percent phenyl mercury urea), Puratized N-5-E (10 percent phenyl mercuric triethanol ammonium lactate).

METHOXYCHLOR (*para*-methoxyphenyltrichloroethane)

Methoxychlor is more effective than DDT on certain insects and is less poisonous to humans. It causes less injury than DDT to beans and vine crops, but damages tomato and corn.

NICOTINE

Aphids can be controlled with a nicotine-soap solution, made from ½ pint of nicotine sulfate and 2–3 pounds of soft soap in 50 gallons of water. Nicotine sulfate is very toxic to aphids in a strength of 1 part to 600 of water (0.06 percent nicotine). Soaps are used with nicotine sulfate and water to liberate the nicotine and to increase the wetting and spreading qualities. Nicotine is often used in a combination spray for various pests.

Nicotine-lime dust (4 percent) is made from 10 pounds of nicotine sulfate and 90 pounds of hydrated lime. Twenty-eight pounds of a free-nicotine concentrate powder (containing 14 percent nicotine) may be substituted for the 10 pounds of nicotine sulfate in 100 pounds of diluted dusts. This material is easier to mix than the liquid nicotine.

PARATHION (diethyl *para*-nitrophenylthiophosphate)

Parathion is remarkably effective against a wide range of insects, e.g., mites (red spider), aphids, Mexican bean beetle, corn borer, onion thrips, and cabbage worms. It should not be used on edible crops within 3–4 weeks of harvest or after the edible portion has formed as in the case of beans. It is used as a spray or dust and is compatible with most insecticides and fungicides, but not with strongly alkaline materials. Precautions must be taken for the operator when handling, mixing, and applying this and phosphate insecticides. Parathion is extremely dangerous if inhaled or absorbed through the skin. Repeated inhalations or skin contact may, without symptoms, progressively increase susceptibility to parathion poisoning. If one is unable or unwilling to take the precautions printed on the package and otherwise prescribed by the manufacturer, it is suggested that one of the alternative recommendations be followed.

PYRETHRUM

Pyrethrum, made from species of daisy-like flowers (*Chrysanthemum*), contains active volatile oils or pyrethrins which are extremely toxic to many insects, e.g., cabbage worms, but not to humans in the common dilutions. Pyrethrum paralyzes insects by contact; it has little stomach poison action. Some pyrethrum extracts are sold as mixtures with soap or alcohol as dissolving

agents for use as a spray. Others contain no emulsifying agent, and soap must be added. Pyrethrum should be kept in tight containers.

Quinone Compounds

Spergon (tetrachloro-*para*-benzoquinone) is a useful seed disinfectant; particularly for peas, lima beans, and sweetpotatoes. Phygon (2,3-dichloro-1,4-naphthoquinone) is a seed treatment for corn and certain other vegetables.

Rotenone

Rotenone is the insecticidal constituent in derris, timbo, and cube roots. It is effective for flea beetles, cabbage worms, bean beetles, and many other pests, and is safe to use on maturing vegetables. Rotenone dusts should be kept in tight containers, and applied preferably in late afternoon to avoid sunlight. They are applied with a nonalkaline, inert carrier, such as finely ground tobacco, dusting gypsum, fine clay, or wheat flour. When rotenone and nicotine are used together, sulfur should be added to prevent the nicotine from destroying the rotenone.

Ryania

Ryania is, like rotenone, a plant product. It is obtained by grinding the stems and roots of ryania, a tropical plant. Ryanodine is the active ingredient. It is effective against the European corn borer.

Sabadilla

Sabadilla is made from ground seeds of a lily (*Schoenocaulon*) found in South and Central America. A 10–20 percent dust controls, among other insects, the squash bug. Its toxic action is not as long lasting as could be desired.

Spreaders, Stickers, and Wetting Agents

A number of spreaders, stickers, and wetting agents are on the market, e.g., a sodium salt of an alkyl naphthalene sulfonic acid (Vatsol OS), sodium monosulfonate, *ortho*-butylphenylphenol (Areskap), aromatic monosodium sulfonate (Ultrawet), Orvus, and Orthex. Follow the manufacturer's directions.

SULFUR

Flowers of sulfur are sometimes broadcast to increase the acidity of the soil and thus to check potato scab (see Chapter 10). Dusts that contain sulfur should not be used on cucurbit crops.

In the organic sulfurs, Arasan (tetramethyl thiuramdisulfide)

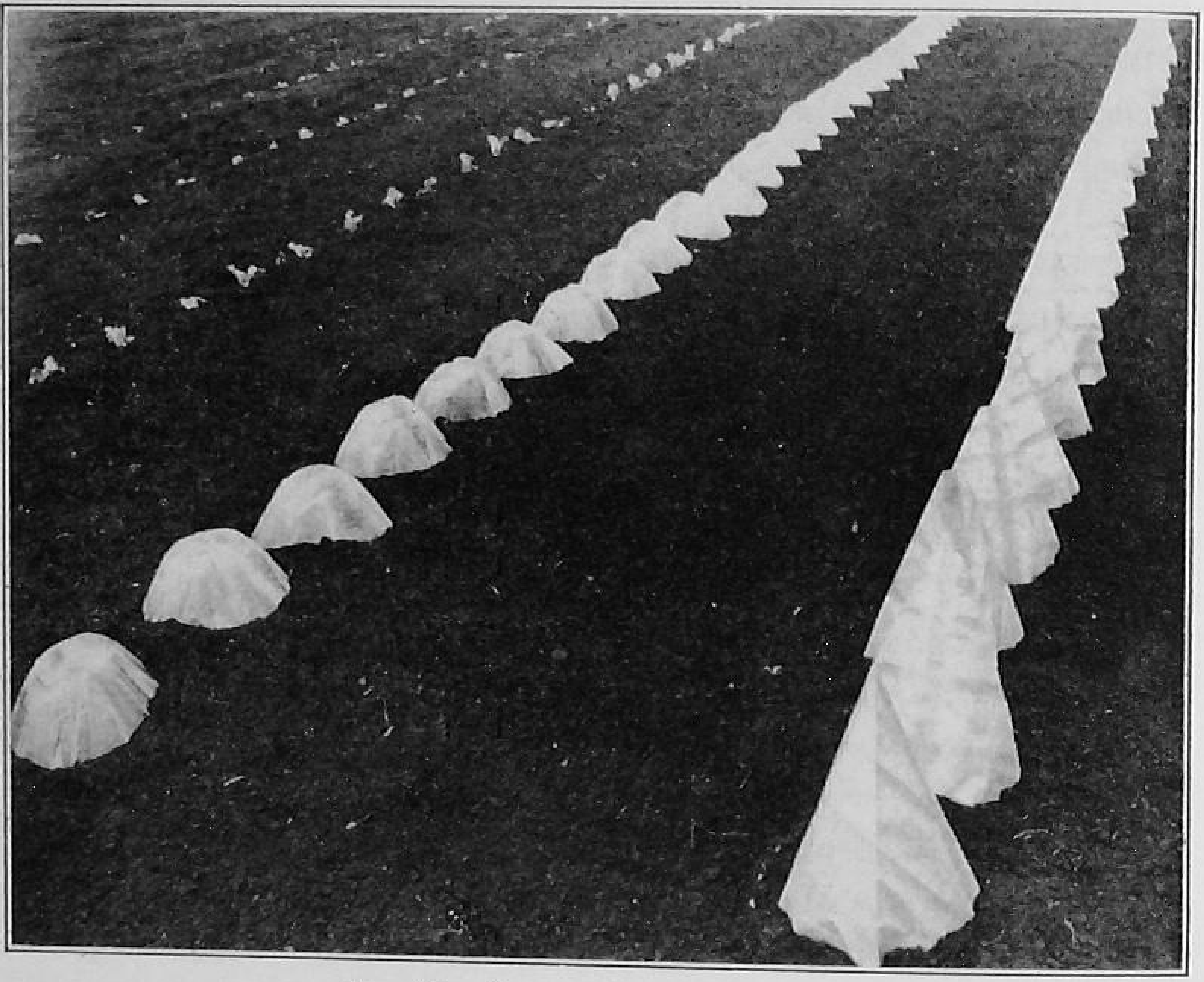

FIG. 77. Paper plant protectors.

is highly effective against molds on seed and in protecting sown seed against decay, damping-off, and root rot. Arasan SF is a slurry form (powder suspended in water). Treated stored seed is protected against weevils and similar insects. Tersan (tetramethyl thiuramdisulfide) is useful as a pellet of dust on onion seed against smut and, as a dip, for stem rot of sweetpotato.

ZINC (see also Cambamates and Chromates)

Zinc oxide (1½–2 percent) is useful for treating celery, parsnip, and spinach seed; it can also be used on crucifers and some other crops.

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